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GEOTHERMAL FORCED-AIR HEATING SYSTEM FOR A RESIDENCE

Prepared for

MONTANA DEPARTMENT of NATURAL RESOURCES and CONSERVATION

GEOTHERMAL FORCED-AIR HEATING SYSTEM FOR A RESIDENCE

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CONTENTS

I. Introduction:

A. Purpose: The purpose of this project was to establish a model to demonstrate the use and effectiveness of geo-thermal energy as a source of space heating for a single family residence in the Helena area. The demand for energy for space heating continues to grow, and traditional forms of energy, i.e. natural gas, oil, propane, are dwindling in supply. Because of finite supplies of fossil fuels renewable alternative forms of energy will need to be developed and employed on a large scale basis to augment and replace existing energy forms.

B. Scope: Specifically the grant was awarded for the purposes of constructing and operating a model home heating system utilizing geo-thermal energy. This was accomplished, but the overall project encompassed a greater effort, and it is the hope of the grant recipiants that work accomplished will be benefical to others examining the potential of geo-thermal energy sources. Unique features of geo-thermal energy became more and more evident as the work took place.

Unlike other forms of alternate energy such as solar, wind, refuse conversion to methane, etc.; geo-thermal energy is site specific. The energy source, on a home heating use basis, is available only where it occurs naturally. It lacks the features of solar energy which occurs everywhere, albeit terrain and weather conditions are limiting factors as to its effectiveness. In those areas where geo-thermal does exist it can be used as an energy source.

Another characteristic is the geo-thermal source itself. Geo-thermal sites have many variables. In making optimum use of a geo-thermal energy source a detailed analysis must be made of the specific geo-thermal resource area.

A final unique characteristic of geo-thermal as opposed to alternnate forms of energy is the finite features of some deposits. In the case of the energy source of this applicant the energy is in the form of hot water. As is the case with any underground water deposits, acquifers contain only a certain amount of water-bearing capacity, and further, recharge at only a given rate. While geo-thermal energy is clearly an alternate to coventional sources it does have finite qualities and therefore must be viewed in the proper context with respect to renewable characteristics.

C. Project Location: The location of the project is west of Helena approximately two and one half miles. The property is the site of the hot water springs used in the early part of this century to supply the Broadwater natatorium, approximately one and a half miles east of the site. Limited development of the hot water springs occurred by constructing a gathering system and in turn a gravity flow through

pipes to serve the natatorium site. During the earth quakes of 1935 the supply lines were broken. The lines were repaired, however, the operation was shut down in 1939 and since that time the spring flow has been into Ten Mile Creek. The specific project area in this grant is in the N 1/2 Section 28, T-11-N, R-4-W, M.P.M. The site of the demonstration model home lies approximately 900 feet from Ten Mile Creek and is approximately 500 feet from the apparent center of the geo-thermal source of energy. The property is a narrow alluvial valley floor with sloping hill sides with rock outcroppings. See map on page 12.

D. Goals: It was the specific goal of the applicant to construct a dwelling and demonstrate the ability to heat that dwelling with geo-thermal energy.

Developing a heating system for a dwelling did require specific research and actions, but questions arose as to a geo-thermal source of energy. Any individual that has access to such resources or is considering the development of such a resource must also consider such factors as area geology, source of the hot water, quality of water, life of the geo-thermal source, and then adaptation to a usage.

Optimizing the use and benefits of the available energy from the source are considerations that any individual involved in a development of this nature must address.

The recipient of this grant did investigate these questions on a limited basis and determined answers with a varying degree of success. Full knowledge of the potential for this site was limited because of the lack of technical knowledge available, financial requirements and time considerations.

It is hoped the information provided in this report will provide specific information on a heating system, and additionally provide guidance and insight, and perhaps answers to those individuals working in the area of geo-thermal resources.

II. Project Implementation:

A. Developement of resource information. From the beginning of this project it was necessary for the applicant to determine the nature of the geo-thermal source of energy. Defining the characteristics of the supply, and to the extent possible the amount of hot water available.

Initial observations were made of the area. From visual inspection of the site it was evident there was a hot water source emerging from underground sources. From the limited development of three springs and the crude in place collection system it was determined the flow was approximated 200 gallons per minute of water with a temperature of 146^{o}-150^{o}F.

The applicant further attempted to define the area of geo-thermal activity with the use of test holes dug with a backhoe. Excavations made to a 10 foot depth helped to identify the area, and give a general location of areas to drill wells. Through the use of this technique it appeared the geo-thermal source occurred in a 300 foot perimeter area. Six wells were drilled with the idea of determing the extent of the geo-thermal deposit. Below is description of the well drilling activity:

Well Number	Depth	Gallons/min.	Temperature
1	90	100	138^{O}F
2	120	70	132^{O}F
3	212	400	152^{O}F
4	115	80	115^{O}F
5	200	20	Cold
6	350	800	152^{O}F

Well number 5 was drilled outside the immediate area and showed no evidence of hot water. Well number 6 proved to be the most productive well since it did produce 800 gallons per minute. Well number 3, the well utilized for the geo-thermal demonstration model, also proved to be a productive well. After pumping well number 3 for a period of 72 hours the draw down was 11.2 feet. Temperatures of the water remained constant throughout the test at 152^{O}F. See plot layout page 13.

A necessary step in the project was to determine the chemical analysis of the water source. Tests taken of the water showed results as follows:

	Milligrams/Liter
Calcium (CA)	9.1
Magnesium (Mg)	.3
Sodium (Na)	170.0
Potassium (K)	5.9
Bicarbonate (HCO_3)	193.0
Sulphate (SO_4)	180.0
Chloride (Cl)	34.0
Flourine (F)	11.0
Nitrates (NO_3)	.0
Total Hardness (as $CACO_3$)	24.0
Total Dissolved Solids	598.00
PH	7.4

This data did not vary significantly from earlier tests made of water by the United States Geological Survey. See appendix A for water quality report.

B. Analysis of resource. Consultants were utilized in analyizing the extent and quality of the resource. The primary consultant with respect to the acquifer was Darrel E. Dunn a geologist-hydorlogist associated with Earth Science Services, Inc. A geological consulting, a firm in Bozeman. Report appendix B. Mr. Robert Leonard, a staff hydrologist with the Helena USGS office, has been in the process of preparing data on geo-thermal sites in Montana. His report on the water quality is contained in appendix A. Others contemplating the use of geo-thermal energy should contact Mr. Leonard for existing data.

Max Botz a hydrologist with Westech in Helena was also used as a consultant.

In addition, cooperation and some analysis work was obtained through resource people existing governmental organizations. Mr. Robert Chadwick from Montana State University served as a source of information and made on site inspections. Some resistivity tests were run in the area as part of student class work at the geology school in Bozeman, but information derived was not conclusive.

Definitive information about the potential for the resource was not conclusive. Because of the lack of detailed information it was not determined what the sustained output of acquifer is. Estimates run as high as 2,475 gallons per minute, but this cannot be substantiated on a continual basis over an extended period of time.

It was suggested that drilling to perhaps a depth of 1,000 feet may produce higher temperatures and greater flows, however, availability of drilling rigs capable of these depths in the Helena area, and financial considerations associated with obtaining this kind of machinery precluded the applicant from investigating in detail the supply.

The conclusion can be made, based on the evidence obtained from drilling and analysis by consultants, that sufficient quantities of hot water exist to support a rather extensive development.

C. System design for demonstration model. Basic investigation was made into the use of geo-thermal resources for space heating and energy production. Throughout the world, and in the Western U.S. geo-thermal resources have been employed.

Some of the most sophisticated developments occur outside the U.S. Both Iceland and New Zealand have employed the use of geo-thermal energy in the generation of electrical power. These resources differ substantially from the resource located west of Helena. Temperatures are much higher and the area involved is large.

Perhaps more applicable are those activities and deposits nearer to Montana; of particular interest is the area around Klamath Falls, Oregon. There space heating using geo-thermal energy is extensive. Both large complexes and individual homes are utilizing the hot water source. Techniques used there merit consideration for Montana developments, however, because of the type of geological formations and the nature of the acquifers, specifically at Broadwater site; a different approach was necessary for demonstration model.

Typically the method employed in the Oregon area is a down hole closed loop heat exchanger system. Because there are flowing acquifers at rather deep depths homes are clustered on one well to reduce well drilling costs per dwelling heated.

After an evaluation of information available and on advice from consultants it appeared a forced air system utilizing a direct flow of the hot water resource through a fin type heat exchanger installed in a furnace would be the most appropriate method of providing space heat.

Consultants used in the system design were James K. Balzhiser a mechanical engineer from Eugene, Oregon. See appendix C.

Providing a valuable assistance was Mr. Joe G. Keller of EG & G Idaho, Inc. Mr. Keller provided information on equipment and sizing of the unit. See appendix D.

D. System Components. The demonstration model consisted of the following major components. See drawing page 14

1. Well and pump.
2. Piping from well to house.
3. Furnace system.
4. Domestic hot water heater.
5. Controls.

These various components are described in more detail in the following.

1. The well number 3 was utilized as the geo-thermal source for the project. Well number 3 had been pump tested at 400 gallons per minute with a maximum draw down of 11.2 feet. Water temperature was constant at 152^{O}F. A one horsepower Jacuzzi Centrifrigal pump was installed using hot water seals. Initally the pump was set at at pumping rate of 12.5 gallons per minute.

2. The dwelling is located 500 feet from the location of the hot water well. One inch interior diameter black iron pipe was used as the conduit to transfer the hot water between house and the well and return to the acquifer. Other forms of specialized pipe for handling hot water

are available on the market, however, not locally. Recommendations by consultants indicated the corrosive nature of the water was not severe enough to warrant the added expense. The iron pipe used should remain serviciable for 40 years before any breakdown because of corrosion from the hot water. While the corrosive characteristics of the hot water seem slight there does appear to be some corrosive action caused by the existing soil. On reexamination of the pipe where it was allowed to come in contact with the existing soil some evidence of corrosion is present.

The pipe was installed in a trench four feet deep. A considerable amount of blasting was necessary because of bedrock encountered. The pipe was laid in a bed of dry sand with a minimum of 6" below and above the pipe. This method of insulation proved effective. The heat loss during the transmission to the house was only a drop 4°F.

In the same trench a return discharge pipe from the heat exchanger was installed in order to return the water to the acquifer.

3. Furnace system: A conventional forced air heat distribution system was installed in the dwelling. This system is typical of forced air systems installed in dwellings utilizing oil, propane, or natural gas burners. The system was installed by Carson Company, a local heating contractor.

   Instead of a burner being installed in the furnace a fin type heat exchanger was installed. The unit was manufactured bv Temp-Trol Corporation. The unit measures 15" x 24" and features four rows of tubing with eight passes.

4. Domestic hot water is also heated utilizing the geo-thermal energy. A unit manufactued by American Appliance which features a full surface double walled heat exchanger was selected. The unit was originally designed for solar adaptations. The solar controls were removed and the unit was installed with a direct flow from the geo-thermal well. The domestic hot water can be heated to a temperature of 140°.

5. Conrols: The significant features of the system included the controls. All of the valves are thermostatically controlled and depending on heat required valves are opened or closed to allow the hot well water to pass through the heat exchanger in the furnace or to the hot

water heater. The valves used are White Rogers zone valves utilized in a domestic hot water heating system. Theromostats also are installed in the hot water heater and furnace to turn the pump on when heat is needed for a furnace or hot water heater. Polar Electric, a Helena firm installed the valves and controls.

The dwelling itself was a newly constructed frame house with brick veneer. There is 1188 square feet on the main floor and 616 square feet finished in the basement. The other area in the basement is utilized as a garage. Insulation rating is R-38 in the ceiling and R-19 on the walls.

No back-up system was installed in the dwelling. In the event of a total failure of the system a fireplace with forced air grate could be utilized to prevent cold weather damage to the property.

The furnace distribution system is fairly standard, and in the event of a failure of the geo-thermal source an electric heating element could be installed in the furnace

E. Problem Areas. For the most part once the system was installed it operated as planned. The temperature in the house could be controlled and the domestic hot water heater provided an adequate source for the occupants of the house. Installing the controls presented some problems but was resolved through trial and error.

One area that may be of concern in the future is the corrosive nature of the soil on the site of the project. While the water from the geo-thermal source is thought not to be corrosive, there may be some corrosive action between the black iron pipe where it may come in contact with the surrounding soil. Other types of pipe may be required, but should be adapted to a specific site.

One problem encountered, but not related to the actual installation involved the rock that required blasing in order to install the pipe from the well to the house.

III. Testing:

Because the system functioned well from the installation extensive testing was not required. The primary area of testing centered around the amount of water pumped by the well and through the system. Equipment used included a recorder obtained from Montana Power Company to measure the time the pump was operating and a temperature recorder obtained from Carson Company was placed in the house to measure the time effects of the system.

In the initial installation of the system the pump supplying the hot water to the house was set to operate on a constant basis of 12.5 gallons flow per minute. Under these conditions there was a tendency for the house to over heat, and obtaining an even temperature was difficult.

The well flow was then adjusted to 6.6 gallons per minute flow and switches installed that only caused the well to pump water when heat was required. The result was an improvement. Temperature levels in the house were maintained at the desired level and energy use was reduced by not running the pump continuously.

Results showed the pump would turn on 3 to 4 times per hour and operate for approximately 5 minutes before turning off. See recordings on pages 15-18.

IV. System Performance:

It is evident from the work completed on the demonstration model a space heating system can be successfully employed using geo-thermal energy. From a design and ease of operation standpoint the system works. Little maintainance is required and for the home occupant changing furnace filters is the primary requirement.

It must be pointed out the system does depend on the availability of electricity supplied by a utility firm. Break in service makes the system inoperable.

To date the system has been reliable, and should continue to operate for the life of the dwelling. As with any home heating system certain parts may wear out and have to be replaced. The forced air motor on the furnace unit, control valves, etc. are items in conventional systems that have a tendency to need replacement from time to time.

The one additional feature in this system that has an adverse effect on reliability is the pump supplying the hot water to the system. As with any water pump the possibility of failure is present.

V. Cost of Project:

The total cost of this demonstration model was $71,785.62. This outlay is in excess of the project grant and represents the cost of construction of a house. A break down of the project cost is shown and further discussed in the economic analysis. Those items with an asterisk are attributable to this project.

House construction (less heating and hot water system)	$45,489.35
Land value	8,500.00
* Consulting Services	1,761.50
* Well Drilling and Testing	6,912.00
* Pump and Controls	1,529.00
* Pipe and Installation	3,365.00
* Furnace System	2,460.65
* Hot Water Tank & Installation	650.00
* Equipment Rental	240.00
* Travel	654.00
* Phone	224.12
	$71,785.62

While the domeonstration model cost was $71,785.62 much of that cost cannot be attributed directly to the project. Those direct project costs run $17,796.27.

VI. Economic Evaluation:

It was demonstrated physically that a geo-thermal source of energy could be used to provide the space heating for a dwelling. More importantly, with respect to the alternative energy program is to determine if in actual fact fossil energy was conserved and the operation of such a system is economical.

Since the energy required to heat the house is contained in the hot water the only additional energy required to operate the system is for the operation of the pump and the fan motor in the furnace system. Conventional forms of space heating energy such as natural gas, electricity, oil etc. were not required and one can only draw the conclusion that other forms of energy were conserved.

It appears the electrical cost of operating the well pump will average about $5 per month and approximately $2.50 for operating the forced air furnace motor. The monthly charge for operating the system is approximately $7.50.

Montana Power has calculated the estimated cost to heat a home of similar size. Using natural gas the annual heating costs would be $320.20 or an average of $26.68 per month. Using electric heat the annual heating charge is estimated at $607.22 or $50.60 per month.

On an operating cost basis there does appear to be considerable savings using the geo-thermal energy.

Annual Geo-Thermal Cost	Annual Natural Gas	Annual Electricity
$90	$320.20	$607.22

The contention that energy is conserved and the geo-thermal source does reduce costs is supported by the electrical usage at the property site. During a 20 month period from January, 1978 through August, 1979 the average monthly electrical charge on the project site was $36.80. The home was occupied by a family of four and in addition to electric lights there was an electric range and refrigerator. The occupant also operated an electric welder part of the time and used head bolt heaters, both of which are heavy users of electricity.

In evaluating the economic aspects of the geo-thermal unit other costs must be considered. There is no question that the initial capital expenditures are greater for the system in the demonstration model. Some of those costs are shown in the preceding section, and are costs that would need to be considered in the installation of a system.

The initial costs will vary from site to site depending on well depth, distance to home from supply, rock blasting, etc. An estimate can be made of the capital outlay to install a system from the costs encountered in this project.

Well drilling (200' @$14)	$2,800.00
Pump and controls	1,500.00
Piping and installation (200' @$3)	600.00
Heat exchanger for furnace	300.00
Hot water heater	400.00
Engineering	150.00
	$5,750.00

If this additional cost, over and above a conventional system, were encountered and was financed at 10% interest over 30 years with the construction of a home, the monthly payment would be $50.49. From the standpoint of economy, a single family unit with this type of expenditure per month may be a marginal situation. What energy cost savings may be realized might be offset by capital costs.

Multi use of a single well or finding sources of geo-thermal energy closer to the surface would reduce the capital expense per dwelling.

VII. Access:

The demonstration model has been available to inspection by the public, and serveral individuals and groups have visited the project. Mr. Frank Gruber, one of the applicants, and the owner of the property may be contacted for an inspection.

In addition to information in this report Mr. Gruber has other publications and information that may be of assistance to those investigating geo-thermal energy sources. Since the completion of the demonstration model Mr. Gruber has constructed a health club utilizing the geo-thermal energy available at the site.

Mr. Gruber's address is 4920 Highway 12 West, Helena, Montana, 406/443-3630.

VIII. Conclusions and Recommendations:

It can be concluded the demonstration model was successful. The applicant did construct and operate a space heating system in a dwelling utilizing a geo-thermal source of energy.

Geo-thermal energy sources are a viable alternative to conventional forms of energy if used on a large scale. For an individual home owner to take advantage of this type of energy source capital costs of installation may be prohibitive.

It can further be stated the alternative energy grogram of the State of Montana was benefical to the success of this project. Information developed in this project and other projects should have a positive effect on the long term energy conservation efforts in Montana.

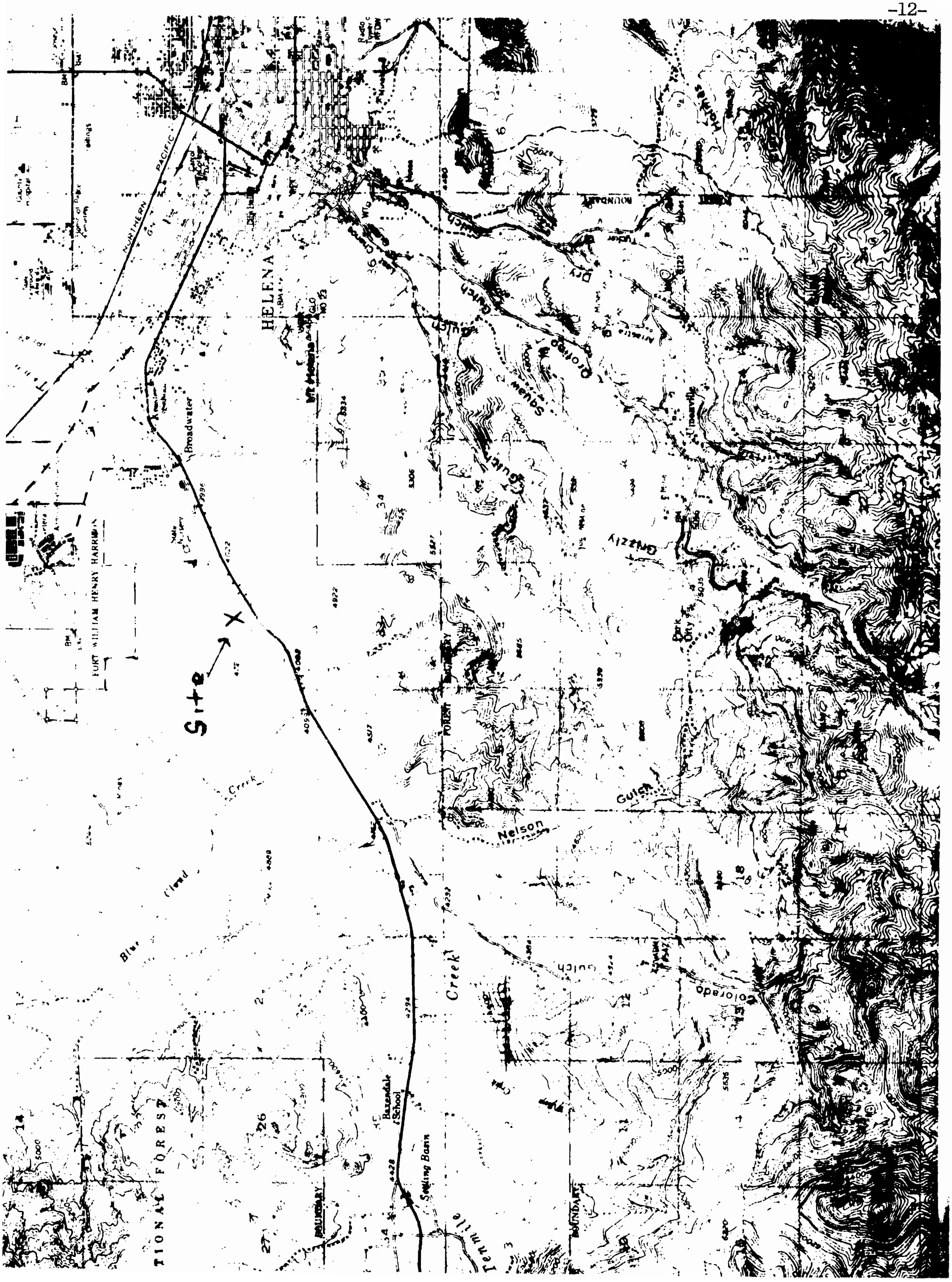
The applicant submits the following recommendations to those individuals regarding a geo-thermal usage.

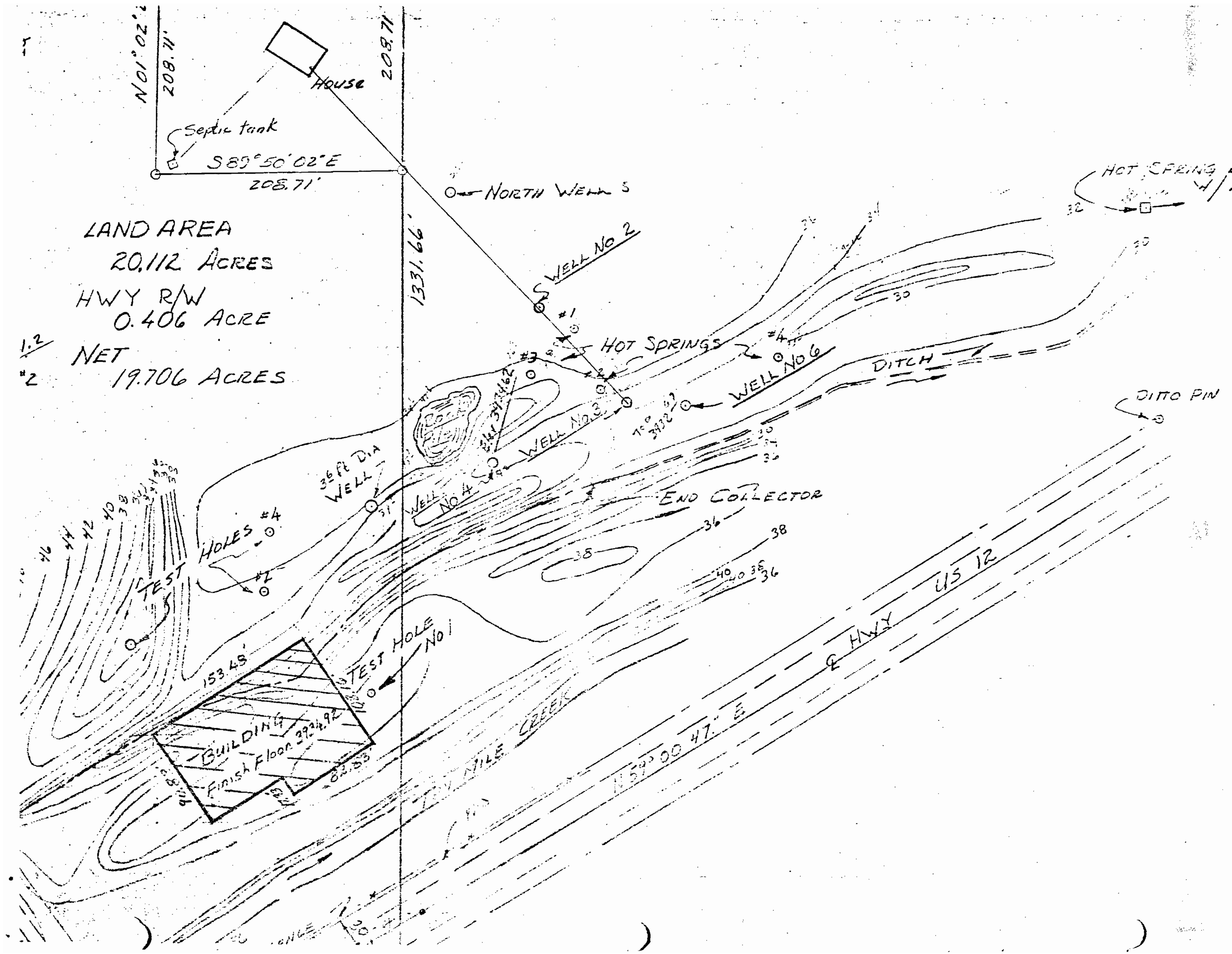
1. A detailed investigation should be made of a geo-thermal site to determine the energy available on a sustaining basis.

2. An overall development plan should be made for an area that would take advantage of multi-uses of a well in order to minimize capital expenditures per use.

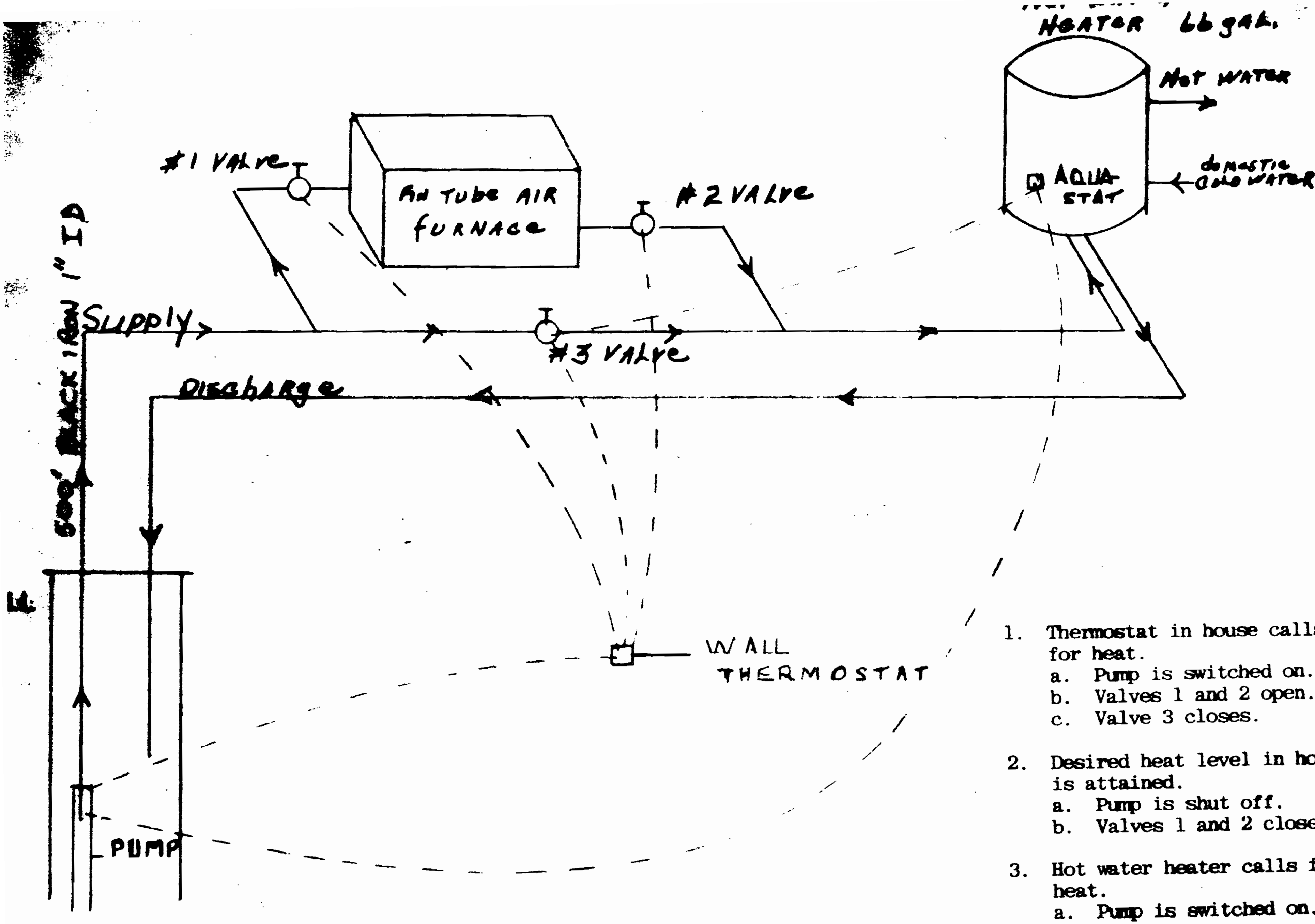
3. Individuals investigating this form of energy should carefully review initial capital outlay in the construction of a system.

4. Because of the frequent natural occurance of hot springs in Montana the state should encourage a policy of utilizing this resource as a way of conserving conventional forms of energy.


HELENA
NORTHERN PACIFIC
FORT WILLIAM HENRY HARRISON
Broadwater
Site
X
Blue
Cloud
Creek
Nelson
Gulch
Grizzly
Colorado
Gulch
Squaw
Gulch
Orofino
Dry
Unionville
Park City
Tenmile
Creek
Baxendale School
BOUNDARY
FOREST
TIONAL FOREST
Spring Barn



N 01° 02'
208.71'
House
208.71'
Septic tank
S 89° 50' 02" E
208.71'
North Well
1331.66'
LAND AREA
20.112 ACRES
HWY R/W
0.406 ACRE
NET
19.706 ACRES
Well No 2
#1
Hot Springs
#3
#4
Well No 6
Ditch
Well No 3
Well No 4
36 ft Dia Well
End Collector
Test Holes
#4
#2
Test
Test Hole No 1
153.45'
Building
Finish Floor
83.53
Creek
N 59° 00' 47" E
HWY
US 12
Hot Spring
Ditto Pin
46
44
42
40
38
36
30

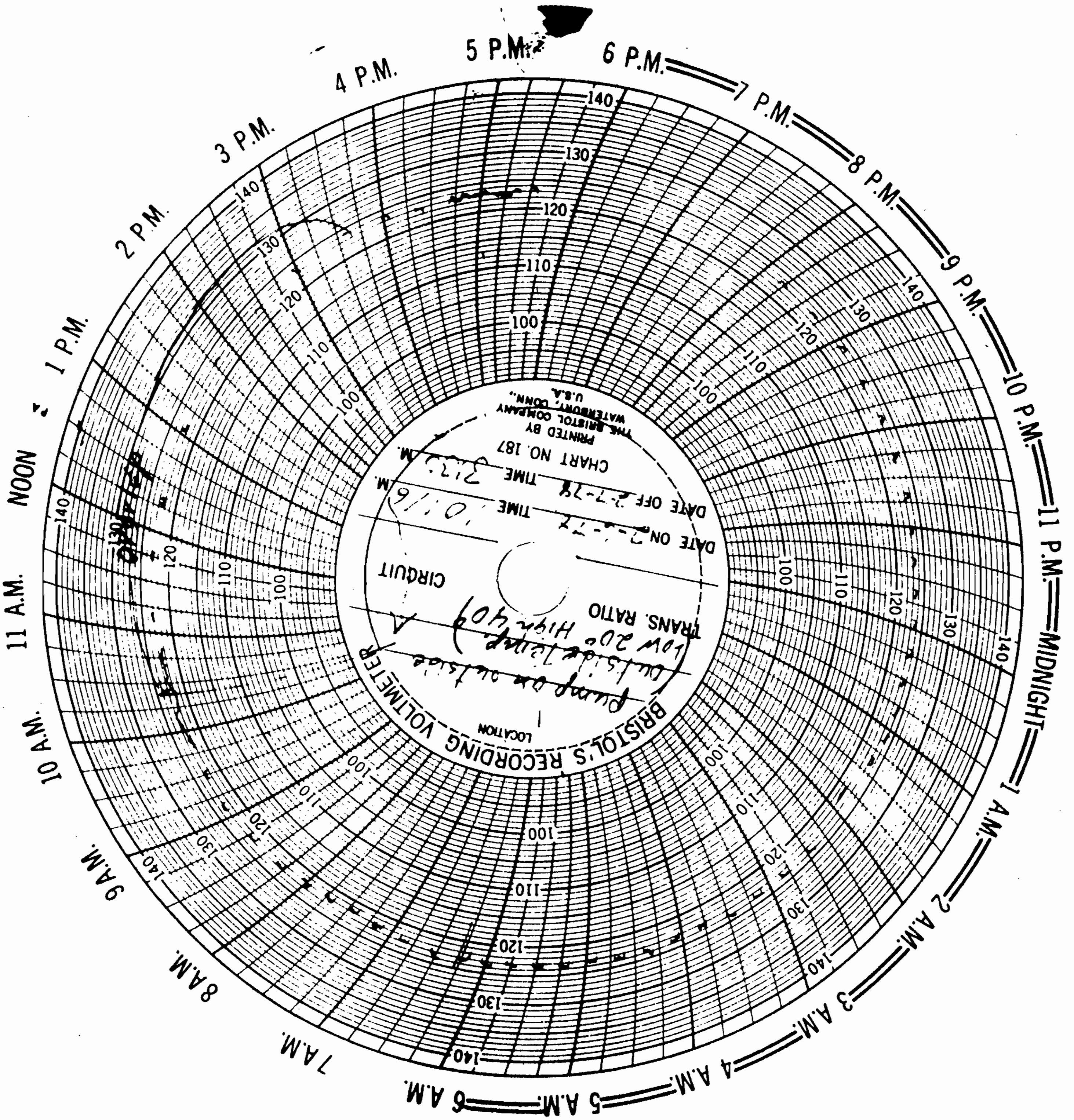


1. Thermostat in house calls for heat.
   a. Pump is switched on.
   b. Valves 1 and 2 open.
   c. Valve 3 closes.

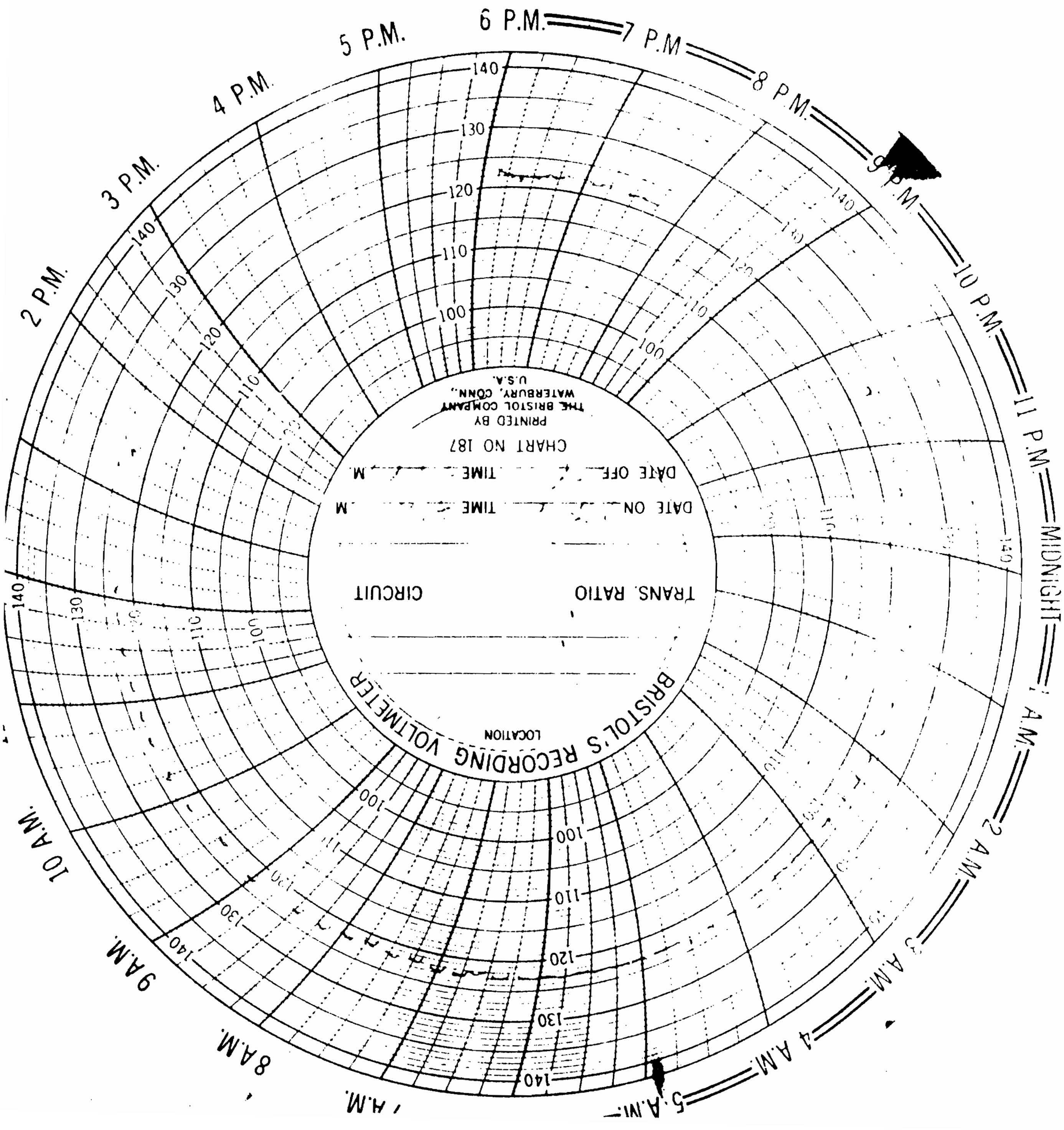
2. Desired heat level in house is attained.
   a. Pump is shut off.
   b. Valves 1 and 2 close.

3. Hot water heater calls for heat.
   a. Pump is switched on.
   b. Valve 3 opens.

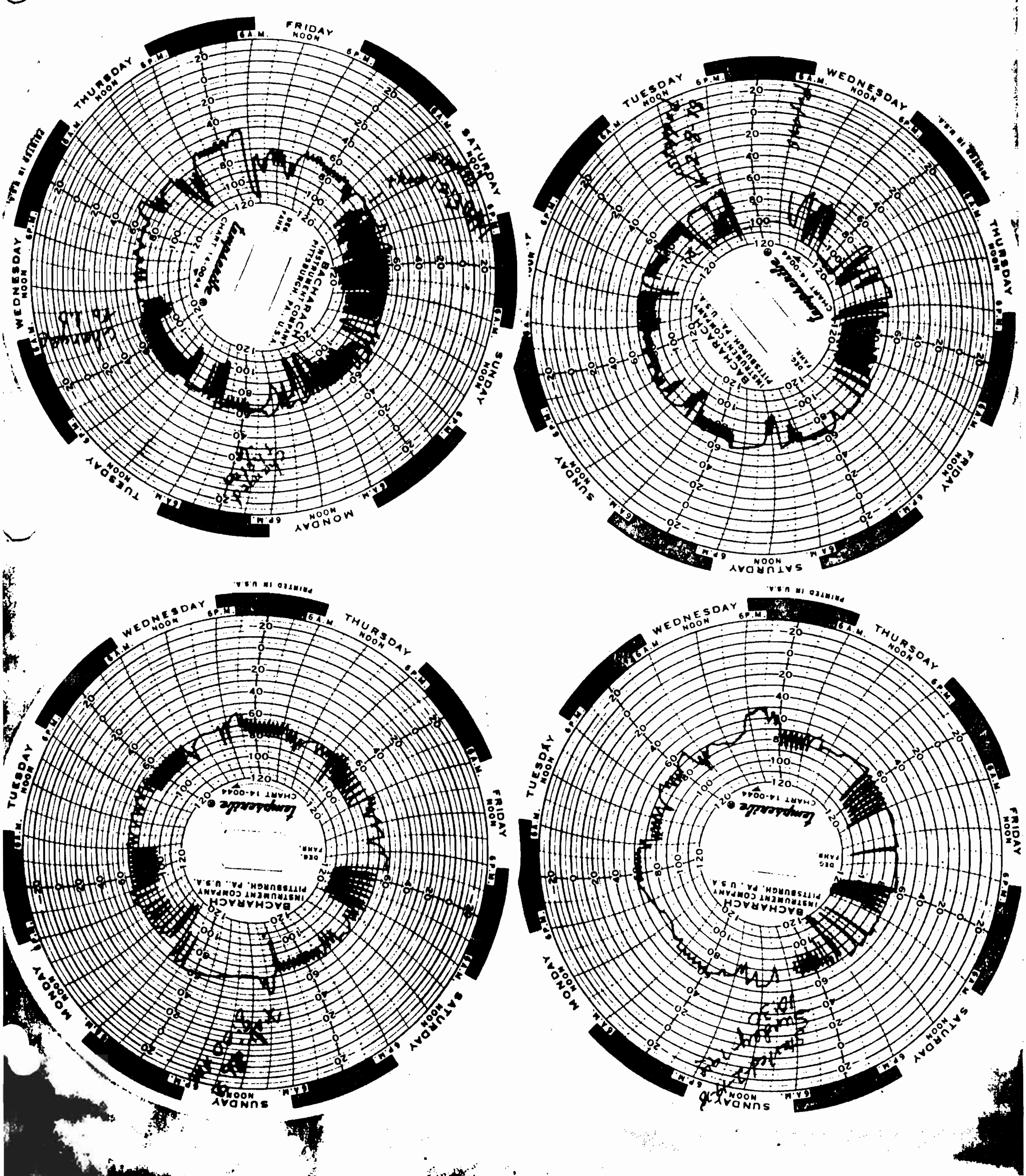
Water pump operating recordings.



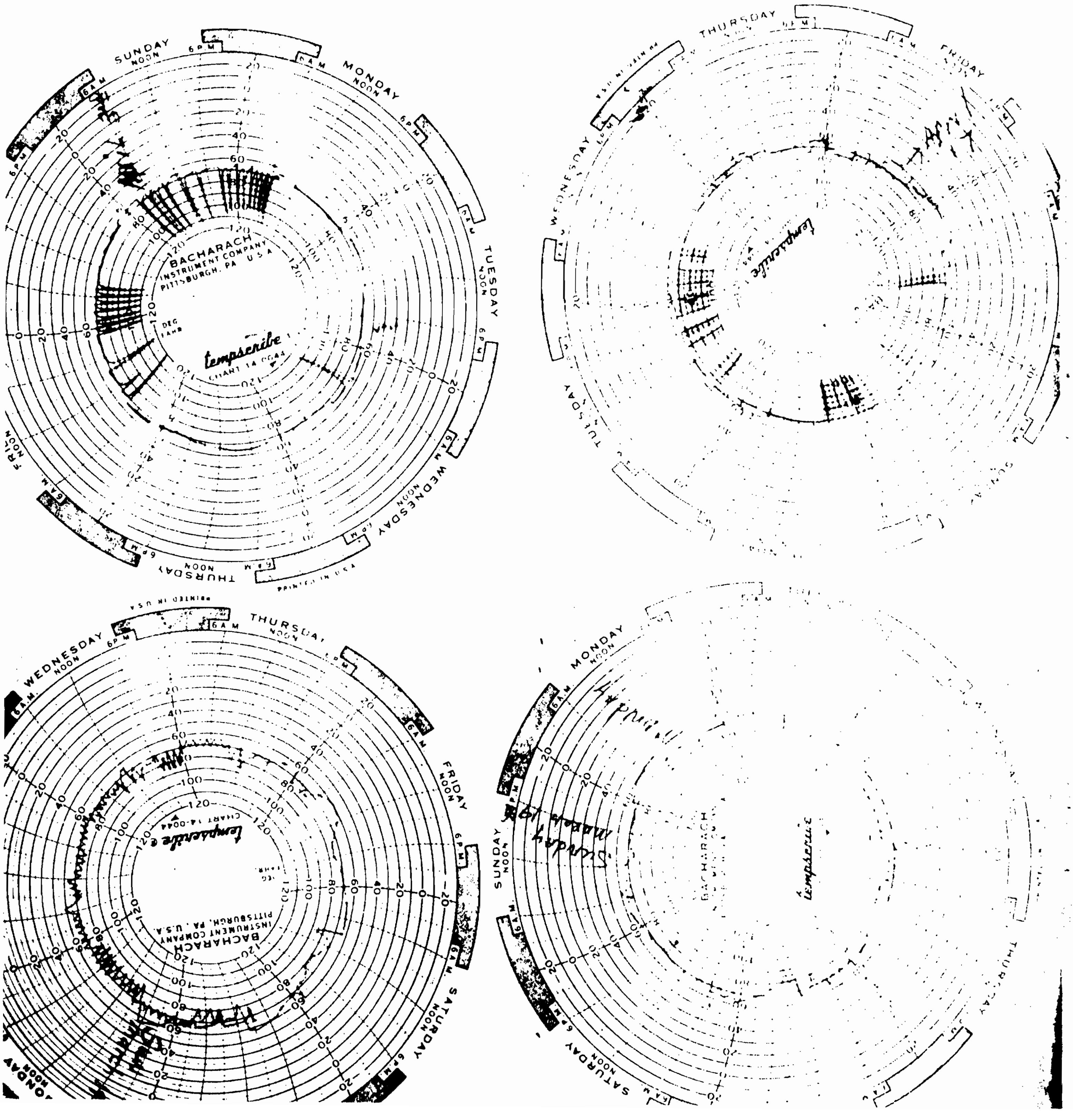
Water pump operating recordings.



Temperature recordings taken at forced air outlet.



Temperature recordings taken at forced air outlet.



SELECTED DATA FROM THERMAL-SPRING AREAS, SOUTHWESTERN MONTANA

By

Robert B. Leonard, Tordis M. Brosten, and Norman A. Midtlyng

INTRODUCTION

During 1975-77 the Montana district of the U.S. Geological Survey collected and assembled data describing the flow, temperature, and chemical characteristics of thermal and related waters. The work was part of an assessment of the geothermal resources of southwestern Montana, excluding Yellowstone Park. The purpose of this report is to present representative data from 24 thermal springs and 3 deep wells where water temperatures exceed 38°C (100°F).

Initially, the data base included references reported by Waring (1965). The data base also included unpublished chemical analyses of water samples and related data collected during 1959-73 by the Montana State Board of Health (now Montana Department of Health and Environmental Sciences), the Montana Bureau of Mines and Geology, and by graduate students for theses. Results of analyses and engineering reports were collected from landowners, and additional published and unpublished data were collected by Geological Survey investigators during 1967-75 (see Selected references).

Tabulation of the data revealed wide discrepancies in reported parameters for some sites. Inadequate description of the sampling sites limited the value of much of the previously reported data, because most of the thermal springs were characterized by multiple outlets. The rate, temperature, and chemical composition of flow at the various outlets commonly differs and may fluctuate seasonally as a result of dilution by shallow ground water. Therefore, most of the sites were revisited to obtain information needed to expand, evaluate, and fill omissions in the data base. Special effort was made to augment data collected during the summer of 1974 at 21 hot springs by other Geological Survey investigators with similar data collected during other seasons.

Field measurements of rate, specific conductance, pH, and temperature of flow at the various outlets, particularly those having the highest temperatures, were compared with previously reported determinations. At some sites partial analyses for chloride or other relatively stable constituents sufficed to confirm similarities or dissimilarities with previously sampled waters. At other sites, more detailed analyses were needed to describe a source initially or to replace dissimilar, and possibly erroneous, information in the preliminary listing. Where correlation

was established, new data were merged with existing data according to location. Samples of associated cool waters were collected to evaluate the possibility that they compose part of the thermal effluent. Some questionable existing data were retained because they were the sole source of information that may describe long-term fluctuations in the chemical and physical properties of the thermal waters.

Chemical analyses and associated data are grouped in tables 1-27 by hot-spring areas, arranged in downstream order according to major river basins, and indexed numerically in figure 1. Locations of individual sites within each area are described by name and by a station number composed of latitude and longitude. Names formerly used to identify the hot springs are shown in parentheses.

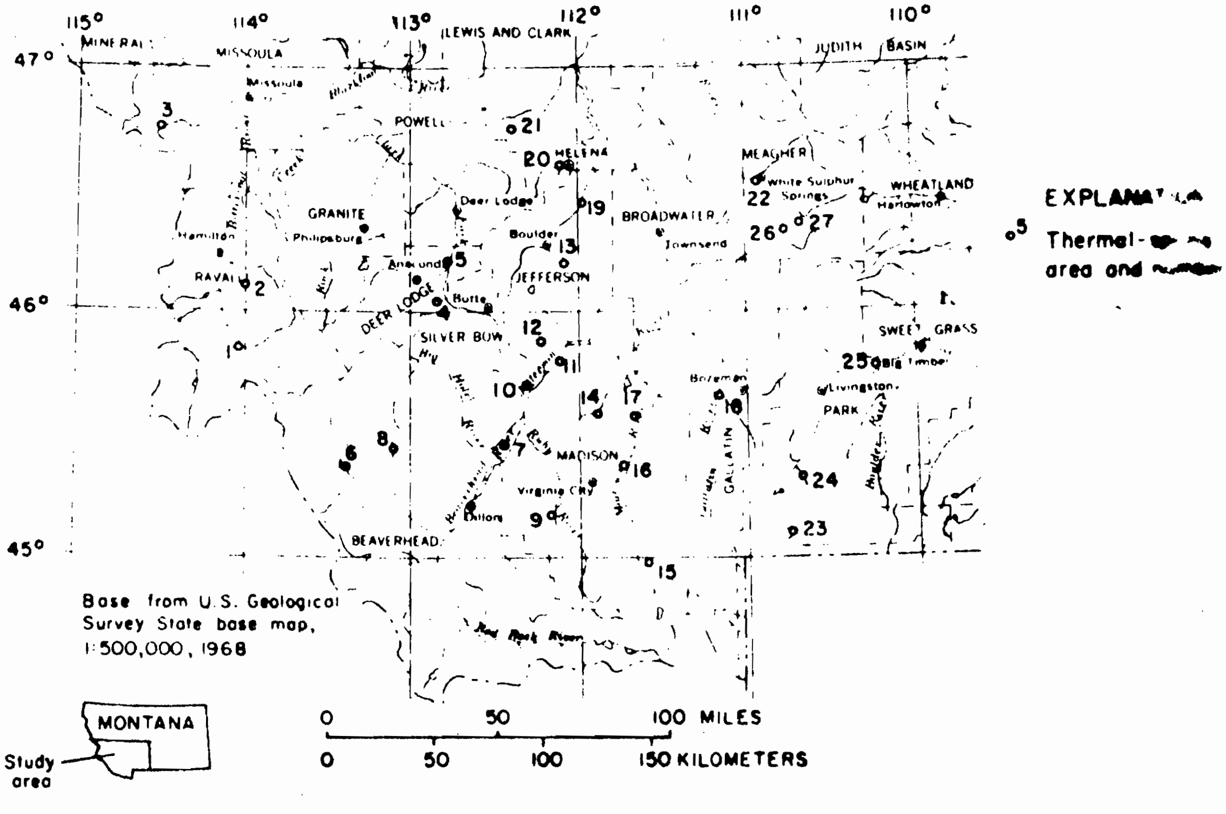


Figure 1.--Location of study area.

Reported rates of flow, particularly at commercially developed springs, vary widely according to the observer or use of the water. A large part of the flow normally occurs as seepage. Where feasible for this study, flow was measured directly using the Hoff or Pygmy current meter, a Parshall flume, or a container of known volume and a stopwatch.

Many apparent discrepancies in data collected in the past at a given site are attributable to different sampling, analytical, or reporting techniques. For example, pH values normally were determined in the field by USGS and in the laboratory by other investigators. Changes in the pH and the concentrations of bicarbonate and calcium commonly accompany cooling and prolonged storage of untreated thermal waters before analysis. The concentrations of dissolved solids for samples collected by USGS are the calculated sum of constituents; although roughly comparable some of the earlier determinations are of the residue on evaporation. Most of the chemical analyses in this report are of samples collected after 1973 by Geological Survey personnel according to techniques outlined by Presser and Barnes (1974) and analyzed by the Survey either in the National Water Quality Laboratory in Denver, Colo., or in research laboratories in Menlo Park, Calif.

All the included data describing composition of gases, stable isotopes, radioactivity, and subsurface temperatures were collected by the U.S. Geological Survey during 1974-77 (tables 28-31). Analysis of samples collected during the current investigation for determination of the composition of gases associated with the thermal waters (table 28) and for their content of the stable isotopes, oxygen-18 (^{18}O) and deuterium (D) (table 29), was expedited by Mariner to ensure comparibility with the results of his previous investigation (Mariner and others, 1976).

The isotopic data are expressed in the delta (δ) notation:

$$\delta_x = \frac{R_x - R_{std}}{R_{std}} \times 10^3$$

where

δ = reporting unit in parts per thousand,
R_x = ratio of isotopic concentration of the sample (D/H or $^{18}O/^{16}O$), and
R_{std} = ratio of isotopic concentration of the standard (Standard Mean Ocean Water, or SMOW, in this report).

Most of the major hot springs and some associated cooler waters were sampled by the Geological Survey for determination of gross alpha and gross beta activity by the Montana Department of Health and Environmental Sciences. Results of the analyses (Larry Lloyd, written commun., 1976, 1977) are included in table 30. Additional samples for determination of dissolved uranium, radium-226, and radon by the National Water Quality Laboratory were collected mainly at sites where the Montana Department

of Health and Environmental Sciences analyses revealed abnormal levels of radioactivity (see table 19).

Subsurface temperatures in selected wells were measured with a thermistor-Wheatstone bridge combination capable of measuring temperatures with a precision of ±0.1 degree Celsius at depths of 3,000 feet (table [illegible]).

DATA

Tables 1-27 are presented in an identical format. Table numbers correspond to hot-spring areas shown on figure 1. Column headings, location numbers, and abbreviations that are not self-explanatory are described below.

The station number is based on the grid system of latitude and longitude. The station number consists of 15 digits. The first 6 digits denote the degrees, minutes, and seconds of latitude; the next 7 digits denote the degrees, minutes, and seconds of longitude; and the last 2 digits form a sequential number for stations within the same 1-second grid. Thus, if two stations have the same coordinates for latitude and longitude, sequential numbers 01 and 02 are assigned.

Station letters identify the data according to source (station name). Station letters and the date of sample collection are continued for each line of data in the tables to facilitate identification of the source of the sample.

Local station-location numbers are shown to the right of some station names. The location numbers are based on the Federal system of land subdivision. The first number indicates the township north (N) or south (S) of the Montana base line; the second, the range east (E) or west (W) of the principal meridian; and the third, the section. The first letter following the section number denotes the quarter section (160-acre tract); the second, the quarter-quarter section (40-acre tract); and the third, the quarter-quarter-quarter section (10-acre tract). Letters are assigned in a counterclockwise direction, beginning with "A" in the northeast quadrant. Consecutive numbers beginning with 2 are added if more than one station is located within a 10-acre tract. For example, hot spring 04N19W07DCD2 is the second station inventoried in the SE¼SW¼SE¼ sec. 7, T. 4 N., R. 19 W.

Abbreviations used in column headings of tables 1-27 are:

AC-FT	Acre-feet
CFS	Cubic feet per second
DEG C	Degrees Celsius
FT	Feet
GPM	Gallons per minute
MG/L	Milligrams per liter
MICROMHOS	Micromhos per centimeter at 25°C
PC/L	Picocuries per liter
UG/L	Micrograms per liter

TABLE 20.--CHEMICAL ANALYSES OF WATER FROM THE BROADWATER (HELENA) HOT SPRINGS AREA

STATION NUMBER	STATION LETTER AND NAME		DATE OF SAMPLE	SAMPLED BY	SAMPLING DEPTH (FT)	INSTANTANEOUS DISCHARGE (CFS)	FLOW RATE (GPM)
463433112074000	A	GRIFFITH COLD SPRING T10N04W32DAD	76-04-07	USGS	--	--	1.8
463456112084501	B	SMALLWOOD-PETERSON COLD SP T10NR04W32BCD	76-04-07	USGS	--	--	121
463538112065500	C	TENMILE CR UPSTREAM FROM NEW BR, BROADWATER	76-11-16	USGS	--	7.1	--
463544112063300	D	BROADWATER HOT SPRINGS AT OUTLET	76-01-30	USGS	--	--	207
	D	BROADWATER HOT SPRINGS AT OUTLET	76-01-30	USGS	--	--	207
	D	BROADWATER HOT SPRINGS AT OUTLET	76-04-27	USGS	--	--	207
463544112063800	E	BROADWATER HOT SPRINGS AT BREAK	76-11-24	USGS	--	--	126
463544112064200	F	BROADWATER HOT SPRINGS AT MANHOLE	64-09-17	MSBH	--	--	75
	F	BROADWATER HOT SPRINGS AT MANHOLE	67-09-21	MBMG	--	--	--
	F	BROADWATER HOT SPRINGS AT MANHOLE	73-09-21	K	--	--	30
	F	BROADWATER HOT SPRINGS AT MANHOLE	74-08-21	RFS	--	--	15
	F	BROADWATER HOT SPRINGS AT MANHOLE	74-08-24	M	--	--	>13
	F	BROADWATER HOT SPRINGS AT MANHOLE	76-01-30	USGS	--	--	--
	F	BROADWATER HOT SPRINGS AT MANHOLE	76-01-30	USGS	--	--	--
463544112064201	G	BROADWATER NORTHWEST COLD PIT	76-09-08	USGS	12	--	--
463544112064202	H	BROADWATER HOT PIT 2	76-09-08	USGS	12	--	--
463544112064203	I	BROADWATER WELL 3	76-10-06	USGS	--	--	60
	I	BROADWATER WELL 3	77-06-07	USGS	--	--	36
463545112061500	J	GLOEGE WELL	76-01-29	USGS	275	--	13
	J	GLOEGE WELL	76-01-29	USGS	275	--	13
463547112063700	K	TENMILE CR DOWNSTREAM FROM DOTSON	76-11-16	USGS	--	7.5	--
463557112060700	L	STATE NURSERY WELL 1	77-06-30	USGS	--	--	--
463600112062000	M	GANNON WELL 1	76-10-08	USGS	--	--	1.0
463610112054600	N	STATE NURSERY WELL 4	77-06-30	USGS	--	--	--
	N	STATE NURSERY WELL 4	77-06-30	USGS	--	--	--
463747112081200	O	NOVAK SPRING	77-06-30	USGS	--	--	--
	O	NOVAK SPRING	77-06-30	USGS	--	--	--
464221112110700	P	BERG SPRING	77-06-29	USGS	--	--	--
	P	BERG SPRING	77-06-29	USGS	--	--	--
464423112110300	Q	ANDERSON SPRING (SITZER GULCH)	77-06-30	USGS	--	--	--
	Q	ANDERSON SPRING (SITZER GULCH)	77-06-30	USGS	--	--	--

STATION LETTER	DATE OF SAMPLE	SPECIFIC CONDUCTANCE (MICROMHOS)	PH (UNITS)	TEMPERATURE (DEG C)	HYDROGEN SULFIDE (MG/L)	HARDNESS (CA,MG) (MG/L)	NONCARBONATE HARDNESS (MG/L)	DISSOLVED CALCIUM (CA) (MG/L)	DISSOLVED MAGNESIUM (MG) (MG/L)	DISSOLVED SODIUM (NA) (MG/L)	PERCENT SODIUM	SODIUM ADSORPTION RATIO	DISSOLVED SODIUM PLUS POTASSIUM (MG/L)
A	76-04-07	486	7.4	9.5	--	240	18	78	12	9.0	7	.3	--
B	76-04-07	484	7.2	7.0	--	240	20	67	18	13	10	.4	--
C	76-11-16	323	8.1	6.0	--	130	26	37	9.7	11	15	.4	--
D	76-01-30	906	8.3	62.2	--	32	0	11	.9	170	90	13	--
D	76-01-30	906	8.3	66.2	--	--	--	12	--	--	--	--	--
D	76-04-27	940	--	59.0	--	34	0	12	1.0	170	90	13	--
E	76-11-24	929	8.2	60.0	--	31	0	11	.9	170	91	13	--
F	64-09-17	--	--	59.0	--	41	0	12	2.0	--	--	--	180
F	67-09-21	--	8.4	65.0	--	26	0	9.6	.4	170	91	15	--
F	73-09-21	--	7.0	63.0	--	33	--	12	.7	150	89	11	--
F	74-08-21	--	--	65.0	--	33	0	12	.8	190	91	14	--
F	74-08-24	796	8.5	62.0	<.5	31	0	11	.9	160	90	12	--
F	76-01-30	872	8.2	66.4	--	29	0	10	.8	170	91	14	--
F	76-01-30	872	8.2	66.4	--	--	--	11	--	--	--	--	--
G	76-09-08	1065	8.0	21.0	--	56	0	20	1.4	190	86	11	--
H	76-09-08	863	7.8	67.0	--	27	0	9.4	.8	180	92	15	--
I	76-10-06	860	7.4	67.8	--	24	0	9.1	.3	170	92	15	--
I	77-06-07	874	--	65.5	--	36	--	13	.8	180	90	13	--
J	76-01-29	728	7.4	19.4	--	260	24	78	16	38	24	1.0	--
J	76-01-29	728	7.4	19.4	--	--	--	79	--	--	--	--	--
K	76-11-16	333	8.0	8.0	--	140	25	39	9.4	18	22	.7	--
L	77-06-30	465	6.7	11.0	--	150	0	45	9.6	50	41	1.8	--
M	76-10-08	395	7.7	11.7	--	160	27	47	9.3	24	25	.8	--
N	77-06-30	373	6.8	10.0	--	150	31	42	10	22	24	.8	--
N	77-06-30	373	6.8	10.0	--	--	--	--	--	--	--	--	--
O	77-06-30	336	7.4	11.0	--	180	39	50	13	8.2	9	.3	--
O	77-06-30	336	7.4	11.0	--	--	--	--	--	--	--	--	--
P	77-06-29	418	7.4	10.0	--	260	42	43	36	7.4	6	.2	--
P	77-06-29	418	7.4	10.0	--	--	--	--	--	--	--	--	--
Q	77-06-30	616	7.3	9.0	--	340	93	73	38	18	10	.4	--
Q	77-06-30	616	7.3	9.0	--	--	--	--	--	--	--	--	--

TABLE 20.--CHEMICAL ANALYSES OF WATER FROM THE BROADWATER (HELENA) HOT SPRINGS AREA--CONTINUED

STATION LETTER	DATE OF SAMPLE	DISSOLVED POTASSIUM (K) (MG/L)	BICARBONATE (HCO3) (MG/L)	CARBONATE (CO3) (MG/L)	ALKALINITY AS CACO3 (MG/L)	CARBON DIOXIDE (CO2) (MG/L)	DISSOLVED SULFATE (SO4) (MG/L)	DISSOLVED CHLORIDE (CL) (MG/L)	DISSOLVED FLUORIDE (F) (MG/L)	DISSOLVED SILICA (SIO2) (MG/L)	DISSOLVED SOLIDS (SUM OF CONSTITUENTS) (MG/L)	DISSOLVED SOLIDS (TONS PER AC-FT)	DISSOLVED SOLIDS (TONS PER DAY)
A	76-04-07	10	276	0	226	16	34	5.0	.2	14	300	.41	--
B	76-04-07	3.7	270	0	221	27	47	3.5	.4	22	308	.42	--
C	76-11-16	2.9	130	0	107	1.5	39	2.9	.3	20	189	.26	3.64
D	76-01-30	6.1	178	0	146	1.4	170	41	11	82	582	.79	--
D	76-01-30	--	--	--	158	--	--	--	--	82	--	--	--
D	76-04-27	5.7	192	--	157	--	170	33	7.9	84	580	.79	--
E	76-11-24	5.8	188	--	154	1.9	190	34	--	--	--	--	--
F	64-09-17	--	190	0	155	--	180	39	9.6	--	--	--	--
F	67-09-21	8.7	190	4	162	1.3	160	40	--	92	600	--	--
F	73-09-21	4.7	--	--	--	--	--	35	--	60	--	--	--
F	74-08-21	5.	[illegible]	--	246	--	190	22	6.2	97	673	--	--
F	74-08-24	5.8	210	5	172	1.1	170	33	9.4	98	597	--	--
F	76-01-30	6.3	152	0	125	1.5	180	34	9.6	93	581	.79	--
F	76-01-30	--	--	--	158	--	--	--	--	--	--	--	--
G	76-09-08	9.1	212	0	174	3.4	220	39	9.7	100	701	.95	--
H	76-09-08	6.3	188	0	154	4.8	180	34	9.3	98	619	.84	--
I	76-10-06	5.9	193	0	158	11	180	34	11	93	598	.81	--
I	77-06-07	6.2	--	--	--	--	--	--	--	--	--	--	--
J	76-01-29	3.4	289	0	237	16	84	12	.7	28	403	.55	--
J	76-01-29	--	--	--	233	--	--	--	--	--	--	--	--
K	76-11-16	3.2	136	0	112	2.2	46	4.7	.6	23	[illegible]	.29	4.30
L	77-06-30	4.1	190	0	160	61	72	13	1.9	34	328	--	--
M	76-10-08	2.7	162	0	133	5.2	38	5.9	.9	22	231	.31	--
M	77-06-30	3.1	140	--	115	36	57	7.6	.7	22	233	.32	--
N	77-06-30	--	--	--	--	--	--	--	--	21	--	--	--
O	77-06-30	2.6	170	--	139	11	44	6.1	.4	25	233	.32	--
O	77-06-30	--	--	--	--	--	--	--	--	27	--	--	--
P	77-06-29	1.4	200	--	164	13	32	5.7	.2	8.8	233	.32	--
P	77-06-29	--	--	--	--	--	--	--	--	9.0	--	--	--
Q	77-06-30	2.7	300	--	246	24	120	8.2	.4	13	421	.57	--
	77-06-30	--	--	--	--	--	--	--	--	13	--	--	--

STATION LETTER	DATE OF SAMPLE	DISSOLVED NITRATE (N) (MG/L)	DISSOLVED NITRATE (NO3) (MG/L)	TOTAL NITRITE PLUS NITRATE (N) (MG/L)	DISSOLVED NITRITE PLUS NITRATE (N) (MG/L)	DISSOLVED AMMONIA NITROGEN (N) (MG/L)	DISSOLVED PHOSPHORUS (P) (MG/L)	DISSOLVED ORTHO. PHOSPHORUS (P) (MG/L)	DISSOLVED ORTHOPHOSPHATE (PO4) (MG/L)
A	76-04-07	--	--	--	.37	--	.02	--	--
B	76-04-07	--	--	--	.01	--	.02	--	--
C	76-11-16	--	--	--	.25	--	--	--	--
D	76-01-30	--	--	.00	--	--	.03	--	--
D	76-01-30	--	--	--	--	--	--	--	--
D	76-04-27	--	--	--	.00	--	.01	--	--
E	76-11-24	--	--	--	--	--	--	--	--
F	64-09-17	.00	[illegible]	--	--	--	--	--	--
F	67-09-21	--	--	--	--	--	--	--	--
F	73-09-21	--	--	--	--	--	--	--	--
F	74-08-21	--	--	--	--	--	--	--	--
F	74-08-24	--	--	--	--	<.10	--	--	--
F	76-01-30	--	--	.00	--	--	.03	--	--
F	76-01-30	--	--	--	--	--	--	--	--
G	76-09-08	--	--	--	1.1	--	--	.12	.37
H	76-09-08	--	--	--	1.6	--	--	.10	.31
I	76-10-06	--	--	--	.00	--	--	--	--
I	77-06-07	--	--	--	--	--	--	--	--
J	76-01-29	--	--	.17	--	--	.03	--	--
J	76-01-29	--	--	--	--	--	--	--	--
K	76-11-16	--	--	--	.21	--	--	--	--
L	77-06-30	--	--	--	.03	--	--	--	--
M	76-10-08	--	--	--	.00	--	--	--	--
M	77-06-30	--	--	--	--	--	--	--	--
N	77-06-30	--	--	--	--	--	--	--	--
O	77-06-30	--	--	--	--	--	--	--	--
O	77-06-30	--	--	--	--	--	--	--	--
P	77-06-29	--	--	--	--	--	--	--	--
P	77-06-29	--	--	--	--	--	--	--	--
Q	77-06-30	--	--	--	--	--	--	--	--
Q	77-06-30	--	--	--	--	--	--	--	--

TABLE 20.--CHEMICAL ANALYSES OF WATER FROM THE BROADWATER (HELENA) HOT SPRINGS AREA--CONTINUED

STA-TION LETTER	DATE OF SAMPLE	DIS-SOLVED ARSENIC (AS) (UG/L)	DIS-SOLVED BERYL-LIUM (BE) (UG/L)	DIS-SOLVED BORON (B) (UG/L)	DIS-SOLVED CAD-MIUM (CD) (UG/L)	DIS-SOLVED LITHIUM (LI) (UG/L)	DIS-SOLVED COBALT (CO) (UG/L)	DIS-SOLVED COPPER (CU) (UG/L)	DIS-SOLVED IRON (FE) (UG/L)	DIS-SOLVED LEAD (PB) (UG/L)	DIS-SOLVED MAN-GANESE (MN) (UG/L)
A	76-04-07	6	0	20	0	10	--	0	0	1	10
B	76-04-07	6	0	30	0	30	--	1	10	2	0
C	76-11-16	--	--	20	--	20	--	--	210	--	10
D	76-01-30	22	0	700	0	570	--	9	60	3	30
D	76-01-30	--	--	--	--	--	--	--	--	--	--
D	76-04-27	--	--	750	--	530	--	--	30	--	--
F	64-09-17	--	--	--	--	--	--	--	0	--	--
F	67-09-21	--	--	880	--	550	--	--	--	--	--
F	74-08-21	--	--	820	--	550	--	--	--	--	--
F	74-08-24	--	--	800	<10	460	<50	<10	70	<100	50
F	76-01-30	20	10	800	1	570	--	6	130	4	50
F	76-01-30	--	--	--	--	--	--	--	--	--	--
G	76-09-08	--	--	780	--	600	--	--	120	--	10
H	76-09-08	--	--	760	--	590	--	--	10	--	40
I	76-10-06	--	--	810	--	600	--	--	110	--	20
I	77-06-07	--	--	--	--	600	--	--	--	--	--
J	76-01-29	15	0	70	0	80	--	5	20	3	30
J	76-01-29	--	--	--	--	--	--	--	--	--	--
K	76-11-16	--	--	60	--	50	--	--	190	--	30
L	77-06-30	--	--	160	--	140	--	--	40	--	8
M	76-10-08	--	--	50	--	40	--	--	170	--	50

STA-TION LETTER	DATE OF SAMPLE	DIS-SOLVED MERCURY (HG) (UG/L)	DIS-SOLVED MOLYB-DENUM (MO) (UG/L)	DIS-SOLVED NICKEL (NI) (UG/L)	DIS-SOLVED SELE-NIUM (SE) (UG/L)	DIS-SOLVED STRON-TIUM (SR) (UG/L)	DIS-SOLVED VANA-DIUM (V) (UG/L)	DIS-SOLVED ZINC (ZN) (UG/L)	DIS-SOLVED CESIUM (CS) (UG/L)	DIS-SOLVED RUBI-DIUM (RB) (UG/L)
A	76-04-07	.0	0	6	1	150	1.6	10	--	--
B	76-04-07	.0	2	7	0	190	2.6	0	--	--
C	76-11-16	--	--	--	--	260	--	--	--	--
D	76-01-30	.0	26	2	0	290	.2	10	--	--
D	76-01-30	--	--	--	--	270	--	--	--	--
D	76-04-27	--	--	--	--	330	--	--	--	--
F	64-09-17	--	--	--	--	--	--	--	--	--
F	67-09-21	--	--	--	--	--	--	--	--	--
F	74-08-21	--	--	--	--	--	--	--	--	--
F	74-08-24	--	--	<20	--	--	--	20	100	60
F	76-01-30	.2	23	0	0	290	.4	10	--	--
F	76-01-30	--	--	--	--	260	--	--	--	--
G	76-09-08	--	--	--	--	550	--	--	--	--
H	76-09-08	--	--	--	--	140	--	--	--	--
I	76-10-06	--	--	--	--	310	--	--	--	--
I	77-06-07	--	--	--	--	--	--	--	--	--
J	76-01-29	.0	43	2	2	560	4.1	30	--	--
J	76-01-29	--	--	--	--	550	--	--	--	--
K	76-11-16	--	--	--	--	260	--	--	--	--
L	77-06-30	--	--	--	--	370	--	--	--	--
M	76-10-08	--	--	--	--	780	--	--	--	--

STA-TION LETTER	DATE OF SAMPLE	TOTAL FILT-RABLE RESIDUE (MG/L)	DIS-SOLVED GROSS ALPHA AS U-NAT. (UG/L)	DIS-SOLVED GROSS BETA AS CS-137 (PC/L)	DIS-SOLVED GROSS BETA AS SR90 /Y90 (PC/L)
D	76-04-27	650	7.7	8.3	6.7

Table 31.--Subsurface temperatures in selected water wells near hot-spring areas--continued

Broadwater (Helena) Hot Springs area--continued

Dundas well. Lat 46°35'44" N., long 112°05'47" W. Reported well depth, 25 ft (77.1 m) below LSD. Water level, 42.6 ft (12.98 m) below MP. MP is top of casing 0.91 ft (0.28 m) above LSD. Date of measurements, Aug. 1, 1977.

Measured depth below LSD (feet)	Measured depth below LSD (meters)	Temperature (°C)	Measured depth below LSD (feet)	Measured depth below LSD (meters)	Temperature (°C)	Measured depth below LSD (feet)	Measured depth below LSD (meters)	Temperature (°C)
0	0	--	90	27.4	11.5	182	55.5	12.5
10	3.0	15.0	102	31.1	11.4	190	57.9	12.6
20	6.1	13.1	110	33.5	11.6	200	61.0	12.6
32	9.8	12.2	122	37.2	11.8	210	64.0	12.6
40	12.2	11.7	130	39.6	12.1	220	67.1	12.6
50	15.2	10.5	142	43.3	12.4	230	70.1	12.9
61	18.6	10.8	150	45.7	12.4	240	73.2	12.9
70	21.3	10.9	159	48.5	12.5	250	76.2	13.3
81	24.7	11.3	171	52.1	12.5	253	77.1	13.4

Broadwater well 3. Lat 46°35'44" N., long 112°06'42" W. Reported well depth, 213 ft (64.9 m) below LSD. Water level, 1.0 ft (0.30 m) above MP. MP is top of casing 1.0 ft (0.30 m) above LSD. Date of measurements, Oct. 6, 1976.

Measured depth below LSD (feet)	Measured depth below LSD (meters)	Temperature (°C)	Measured depth below LSD (feet)	Measured depth below LSD (meters)	Temperature (°C)	Measured depth below LSD (feet)	Measured depth below LSD (meters)	Temperature (°C)
0	0	64.7	70	21.3	66.7	140	42.7	67.2
10	3.0	66.7	80	24.4	66.7	149	45.4	67.2
20	6.1	66.7	90	27.4	67.2	161	49.1	67.2
30	9.1	66.7	101	30.8	67.2	169	51.5	67.2
40	12.2	66.7	110	33.5	67.2	180	54.9	67.2
49	14.9	66.7	120	36.6	67.2	190	57.9	67.2
60	18.3	66.7	131	39.9	67.2	200	61.0	67.2

Table 31.--Subsurface temperatures in selected water wells near hot-spring areas--continued

Broadwater (Helena) Hot Springs area--continued

Broadwater well 3. Lat 46°35'44" N., long 112°06'42" W. Reported well depth, 213 ft (64.9 m) below LSD. Water level, flowing at MP. MP is top of casing 1.0 ft (0.30 m) above LSD.

Measured depth below LSD (feet)	(meters)	Temperature (°C)	Measured depth below LSD (feet)	(meters)	Temperature (°C)	Measured depth below LSD (feet)	(meters)	Temperature (°C)
Date of measurements, Oct. 6, 1976								
10	3.0	67.2	90	27.4	67.2	160	48.8	67.2
20	6.1	67.2	110	33.5	67.2	171	52.1	67.2
30	9.1	67.2	130	39.6	67.2	180	54.9	67.[illegible]
50	15.2	67.2	139	42.4	67.2	190	57.9	67.[illegible]
71	21.6	67.2	150	45.7	67.2			
Date of measurements, June 22, 1977								
0	0	67.1	60	18.3	67.5	121	36.9	67.8
11	3.4	66.7	70	21.3	67.5	130	39.6	67.5
20	6.1	66.7	80	24.4	67.5	141	43.0	67.6
30	9.1	66.8	90	27.4	67.6	150	45.7	67.6
40	12.2	67.0	101	30.8	67.6	160	48.8	67.7
50	15.2	67.5	110	33.5	67.7	165	50.3	67.6
Date of measurements, June 28, 1977								
0	0	63.0	60	18.3	67.7	129	39.3	67.9
10	3.0	66.8	70	21.3	67.7	140	42.7	67.8
20	6.1	67.8	81	24.7	67.7	151	46.0	67.8
31	9.4	67.9	90	27.4	67.7	162	49.4	67.9
40	12.2	67.7	101	30.8	67.8	171	52.1	67.9
51	15.5	67.7	120	36.6	68.0			

Table 31.--Subsurface temperatures in selected water wells near hot-spring areas--continued

Broadwater (Helena) Hot Springs area--continued

Broadwater well 4. Lat 46°35'44" N., long 112°06'43" W. Reported well depth, 240 ft (73.2 m) below LSD. Water level, 3.1 ft (0.94 m) below MP. MP is top of casing 0.5 ft (0.15 m) above LSD. Date of measurements, Sept. 29, 1976.

Measured depth below LSD (feet)	Measured depth below LSD (meters)	Temperature (°C)	Measured depth below LSD (feet)	Measured depth below LSD (meters)	Temperature (°C)	Measured depth below LSD (feet)	Measured depth below LSD (meters)	Temperature (°C)
0	0	26.7	90	27.4	45.2	170	51.8	52.9
11	3.4	31.0	101	30.8	45.7	180	54.9	53.5
20	6.1	31.7	110	33.5	46.8	190	57.9	54.1
29	8.8	33.1	121	36.9	49.5	200	61.0	54.8
41	12.5	35.2	130	39.6	50.1	210	64.0	55.4
52	15.8	36.6	141	43.0	50.8	220	67.1	55.9
61	18.6	38.8	150	45.7	51.6	230	70.1	56.6
70	21.3	40.8	160	48.8	52.5	233	71.0	56.9
80	24.4	44.4						

Broadwater well 4. Lat 46°35'44" N., long 112°06'43" W. Reported well depth, 240 ft (73.2 m) below LSD. Water level, 4.05 ft (1.23 m) below MP. MP is top of casing 0.5 ft (0.15 m) above LSD. Date of measurements, June 22, 1977.

Measured depth below LSD (feet)	Measured depth below LSD (meters)	Temperature (°C)	Measured depth below LSD (feet)	Measured depth below LSD (meters)	Temperature (°C)	Measured depth below LSD (feet)	Measured depth below LSD (meters)	Temperature (°C)
0	0	--	78	23.8	38.6	171	52.1	49.3
5	1.5	19.1	90	27.4	44.7	180	54.9	50.4
10	3.0	19.2	101	30.8	45.0	191	58.2	51.5
20	6.1	21.0	110	33.5	45.4	200	61.0	52.4
31	9.4	24.6	121	36.9	45.6	210	64.0	53.2
40	12.2	28.1	130	39.6	45.8	222	67.7	53.6
51	15.5	30.6	140	42.7	46.2	230	70.1	53.9
60	18.3	33.2	150	45.7	47.2	240	73.2	54.1
71	21.6	37.8	160	48.8	48.0			

Table 31.--Subsurface temperatures in selected water wells near hot-spring areas--continued

Broadwater (Helena) Hot Springs area--continued

Broadwater well 4. Lat 46°35'44" N., long 112°06'43" W. Reported well depth, 240 (73.2 m) below LSD. Water level, 3.63 ft (1.11 m) below MP. MP is top of casing 0.5 ft (0.15 m) above LSD. Date of measurements, June 28, 1977.

Measured depth below LSD (feet)	(meters)	Temperature (°C)	Measured depth below LSD (feet)	(meters)	Temperature (°C)	Measured depth below LSD (feet)	(meters)	Temperature (°C)
0	0	--	80	24.4	44.0	161	49.1	49.4
10	3.0	20.8	90	27.4	45.8	170	51.8	50.4
20	6.1	22.7	101	30.8	46.3	181	55.2	51.6
31	9.4	26.1	110	33.5	46.6	190	57.9	52.5
42	12.8	28.8	121	36.9	46.8	202	61.6	53.6
51	15.5	32.5	130	39.6	47.0	211	64.3	53.9
60	18.3	34.9	141	43.0	47.6	220	67.1	54.1
71	21.6	39.4	150	45.7	48.2	225	68.6	54.1

Gloege well. Lat 46°35'45" N., long 112°06'15" W. Reported well depth, 275 ft (83.8 m) below LSD. Water level, 28.3 ft (8.63 m) below MP. MP is top of casing 1.0 ft (0.30 m) above LSD. Date of measurements, Jan. 29, 1976.

Measured depth below LSD (feet)	(meters)	Temperature (°C)	Measured depth below LSD (feet)	(meters)	Temperature (°C)	Measured depth below LSD (feet)	(meters)	Temperature (°C)
0	0	--	90	27.4	12.6	230	70.1	19.8
32	9.8	10.2	110	33.5	14.0	240	73.2	20.0
40	12.9	10.2	130	39.6	15.0	242	73.8	20.3
50	15.2	10.4	150	45.7	15.8	250	76.2	20.5
60	18.3	11.2	170	51.8	16.9	260	79.2	20.9
70	21.3	11.5	190	57.9	18.0	270	82.3	21.3
80	24.4	--	210	64.0	18.8	275	83.8	21.5

Broadwater well 1. Lat 46°35'45" N., long 112°06'42" W. Reported well depth, 200 ft (61.0 m) below LSD. Water level, 6.6 ft (2.01 m) below MP. MP is top of casing 0.5 ft (0.15 m) above LSD. Date of measurements, Sept. 15, 1976.

Measured depth[1] below LSD (feet)	(meters)	Temperature (°C)	Measured depth[1] below LSD (feet)	(meters)	Temperature (°C)	Measured depth[1] below LSD (feet)	(meters)	Temperature (°C)
0	0	29.1	60	18.3	57.7	110	33.5	64.4
10	3.0	46.2	70	21.3	57.9	122	37.2	65.0
20	6.1	49.1	80	24.4	58.4	132	40.2	65.0
30	9.1	52.6	90	27.4	60.8	142	43.3	65.0
40	12.2	57.6	100	30.5	62.0	146	44.5	65.3
50	15.2	57.7						

[1] Well drilled approximately 20° from vertical.

Table 31.--Subsurface temperatures in selected water wells near hot-spring areas--continued

Broadwater (Helena) Hot Springs area--continued

Broadwater well 1. Lat 46°35'45" N., long 112°06'42" W. Reported well depth, 200 ft (61.0 m) below LSD. Water level, 7.02 ft (2.14 m) below MP. MP is top of casing 0.5 ft (0.15 m) above LSD. Date of measurements, June 28, 1977.

Measured depth[1] below LSD (feet)	(meters)	Temperature (°C)	Measured depth[1] below LSD (feet)	(meters)	Temperature (°C)	Measured depth[1] below LSD (feet)	(meters)	Temperature (°C)
0	0	--	20	6.1	50.6	30	9.1	55.0
11	3.4	48.1						

[1]Well drilled approximately 20° from vertical.

Broadwater well 2. Lat 46°35'46" N., long 112°06'42" W. Reported well depth, 204 ft (62.2 m) below LSD. Water level, 22.3 ft (6.80 m) below MP. MP is top of casing 0.5 ft (0.15 m) above LSD. Date of measurements, Sept. 16, 1976.

Measured depth[1] below LSD (feet)	(meters)	Temperature (°C)	Measured depth[1] below LSD (feet)	(meters)	Temperature (°C)	Measured depth[1] below LSD (feet)	(meters)	Temperature (°C)
0	0	--	80	24.4	47.8	152	46.3	65.0
10	3.0	26.6	91	27.4	51.7	160	48.8	65.0
20	6.1	31.9	100	30.5	54.9	169	51.5	66.7
30	9.1	33.5	109	33.2	57.6	180	54.9	66.7
40	12.2	35.6	120	36.6	61.1	190	57.9	66.7
50	15.2	38.3	132	40.2	63.0	200	61.0	67.2
62	18.9	42.0	140	42.7	65.0	204	62.2	67.2
70	21.3	45.0						

[1]Well drilled approximately 20° from vertical.

Broadwater well 2. Lat 46°35'46" N., long 112°06'42" W. Reported well depth, 204 ft (62.2 m) below LSD. Water level, 21.49 ft (6.55 m) below MP. MP is top of casing 0.57 ft (0.15 m) above LSD. Date of measurements, June 27, 1977.

Measured depth[1] below LSD (feet)	(meters)	Temperature (°C)	Measured depth[1] below LSD (feet)	(meters)	Temperature (°C)	Measured depth[1] below LSD (feet)	(meters)	Temperature (°C)
0	0	--	70	21.3	42.2	130	39.6	62.5
26	7.9	29.3	80	24.4	45.5	140	42.7	63.7
30	9.1	30.2	90	27.4	49.6	151	46.0	65.5
41	12.5	32.8	100	30.5	53.8	160	48.8	66.0
	15.2	35.6	110	33.5	56.9	165	50.3	66.0
	18.9	39.5	120	36.6	59.7			

[1]Well drilled approximately 20° from vertical.

Table 31.--Subsurface temperatures in selected water wells near hot-spring areas--continued

Broadwater (Helena) Hot Springs area--continued

Thomson well. Lat 46°35'49" N., long 112°06'23" W. Reported well depth, 120 ft (36.6 m) below LSD. Water level, 17.0 ft (5.18 m) below MP. MP is top of casing 1.6 ft (0.49 m) above LSD. Date of measurements, Aug. 12, 1977.

Measured depth below LSD (feet)	(meters)	Temperature (°C)	Measured depth below LSD (feet)	(meters)	Temperature (°C)	Measured depth below LSD (feet)	(meters)	Temperature (°C)
0	0	--	40	12.2	15.8	80	24.4	16.0
10	3.0	22.9	50	15.2	15.8	90	27.4	16.4
20	6.1	14.2	60	18.3	15.9	100	30.5	16.6
30	9.1	15.4	70	21.3	15.9			

Broadwater well 5. Lat 46°35'52" N., long 112°06'38" W. Reported well depth, 260 ft (76.8 m) below LSD. Water level, 77.9 ft (23.74 m) below MP. MP is top of casing 1.0 ft (0.30 m) above LSD. Date of measurements, Oct. 6, 1976.

Measured depth below LSD (feet)	(meters)	Temperature (°C)	Measured depth below LSD (feet)	(meters)	Temperature (°C)	Measured depth below LSD (feet)	(meters)	Temperature (°C)
0	0	--	91	27.8	14.7	180	54.9	18.5
10	3.0	12.6	100	30.5	15.1	191	58.2	19.0
20	6.1	13.3	111	33.8	15.6	200	61.0	19.3
30	9.1	13.0	120	36.6	15.9	211	64.3	19.8
40	12.2	12.6	131	39.9	16.4	220	67.1	20.1
50	15.2	12.6	139	42.4	16.8	231	70.4	20.5
59	18.0	12.7	151	46.0	17.3	240	73.2	20.7
70	21.3	13.0	159	48.5	17.6	246	78.0	20.9
82	25.0	14.2	171	52.1	18.1			

Broadwater well 5. Lat 46°35'52" N., long 112°06'38" W. Reported well depth, 260 ft (76.8 m) below LSD. Water level, 91.1 ft (27.77 m) below MP. MP is top of casing 1.0 ft (0.30 m) above LSD. Date of measurements, June 28, 1977.

Measured depth below LSD (feet)	(meters)	Temperature (°C)	Measured depth below LSD (feet)	(meters)	Temperature (°C)	Measured depth below LSD (feet)	(meters)	Temperature (°C)
0	0	--	151	46.0	17.4	211	64.3	19.8
96	29.3	15.0	160	48.8	17.8	220	67.1	20.2
101	30.8	15.4	171	52.1	18.2	231	70.4	20.6
110	33.5	15.7	180	54.9	18.6	240	73.2	20.9
120	36.6	16.1	191	58.2	19.0	251	76.5	21.2
130	39.6	16.6	200	61.0	19.4	260	79.2	21.2
140	42.7	17.0						

Table 31.--Subsurface temperatures in selected water wells near hot-spring areas--continued

Broadwater (Helena) Hot Springs area--continued

Gannon well 2. Lat 46°35'54" N., long 112°06'17" W. Reported well depth, 175 ft (53.34 m) below LSD. Water level, 6.0 ft (1.83 m) below MP. MP is top of casing 1.0 ft (0.30 m) above LSD. Date of measurements, Oct. 27, 1976.

Measured depth below LSD (feet)	(meters)	Temperature (°C)	Measured depth below LSD (feet)	(meters)	Temperature (°C)	Measured depth below LSD (feet)	(meters)	Temperature (°C)
0	0	16.0	70	21.3	12.0	130	39.6	13.7
10	3.0	11.7	80	24.4	12.2	140	42.7	13.9
20	6.1	11.7	90	27.4	12.6	150	45.7	14.3
30	9.1	11.4	100	30.5	12.8	160	48.8	14.5
40	12.2	11.0	111	33.8	13.2	171	52.1	14.7
50	15.2	11.2	120	36.6	13.4	174	53.0	14.7
60	18.3	11.5						

Gannon well 1. Lat 46°36'00" N., long 112°06'20" W. Reported well depth, 240 ft (73.2 m) below LSD. Water level, flowing at MP. MP is top of casing 1.0 ft (0.30 m) above LSD. Date of measurements, Oct. 8, 1976.

Measured depth below LSD (feet)	(meters)	Temperature (°C)	Measured depth below LSD (feet)	(meters)	Temperature (°C)	Measured depth below LSD (feet)	(meters)	Temperature (°C)
0	0	54.7	80	24.4	56.3	160	48.8	57.2
10	3.0	54.9	90	27.4	56.5	170	51.8	57.2
20	6.1	54.7	100	30.5	57.0	180	54.9	57.2
30	9.1	55.0	112	34.1	57.0	190	57.9	57.2
40	12.2	55.2	120	36.6	57.2	200	61.0	57.2
50	15.2	55.6	130	39.6	57.4	210	64.0	57.4
60	18.3	55.9	140	42.7	57.2	221	67.4	57.2
70	21.3	56.1	150	45.7	57.2	230	70.1	57.2

Earth Science Services, Inc.

Executec Building
1115 N. Seventh Avenue
Bozeman, Montana 59715
Phone: (406) 587-8501

7 July 1977

Mr. Frank Gruber
6240 Center Drive
Helena, Montana 59601

Dear Frank:

I have analyzed the pump test data you sent, and I will answer the questions in your letter of June 8 as well as I can. Your first question was whether you could get more hot water if you drilled another well; and if you did, where should it be located. I think there are two items to consider, (1) can you get more hot water, and (2) what would the water temperature be. Regarding the first item, the information we have suggests that Well #3 may be located in about the right place for maximum yield of water. My reasoning is that I think the hot water in the area is rising primarily along conduits formed of heavily fractured bedrock. These conduits are more permeable than the surrounding bedrock. Consequently, a well that penetrates a conduit will be in the most permeable material and will have the highest yield. Prior to the original excavating of springs in the area, locations of the conduits were probably the sites of hot water seeps or other surface indications of hot water. These areas of surface indications were probably chosen for the sites of the developed springs. Therefore, the springs, especially the ones currently flowing, are likely to mark the location of the most permeable bedrock and the best location for high yielding wells. Well #3 is located between two springs and close to them, so I think it is in a good spot for maximum yield. A location near Spring #4 would be another likely location for high yield, and the bubbling area in the old creek bed would be another prime site, but it is close to well #3.

With regard to item 2, water temperature, Well #3 may not be in the best location, because it is located close to the cooler water in Well #4, and it is hydraulically connected to Well #4. If Well #3 were pumped heavily, I think it would bring in a considerable amount of the cooler water. A well located near Spring #4 might not be any better because of the possibility of cooler water to the north and to the east. A better location for maintaining temperature might be in the middle of the area bounded by the four springs, the bubbles, and the reach of Tenmile Creek that doesn't freeze. However, a well located in the middle of that area might not yield as much water as Well #3. Its initial water temperature might not be as high as the temperature in Well #3 either, but I suspect the temperature would tend to decline less at equivalent pumping rates.

My interpretation of the subsurface conditions is that there is an irregular shaped conduit with an indistinct boundary around Springs 2, 3, and the bubbles, and that another such conduit may be present near Spring #4. The difference in "static" water levels in Well #3 and Well #4 indicates that hot water seeps laterally from the conduits into the surrounding, less permeable bedrock. It should move more slowly there and lose heat by conduction to the ground surface through the rock, and by mixing with cool ground water in fractures that are not well connected with deep, permeable, hot-water bearing fracture zones. If a well penetrating a hot-water conduit is pumped hard enough it will reverse

the horizontal component of the flow direction so that cool water is brought into the conduit instead of hot water leaving it. This is a simplified description of the subsurface conditions, but it might serve as a quick explanation. The water table map indicates that hot water is coming toward the surface near the unfrozen reach of Tenmile Creek, but I see no seeps to suggest even a hazily defined conduit.

To summarize my comments on your first question, I doubt if you will get more gallons per minute of hot water from another well. You might, however, succeed in getting more BTU's for a given pumping rate from a well located in the middle of the area bounded by the aforementioned springs, bubbles, and unfrozen reach. A test well would be necessary to test this possibility.

Your second question is related to gallons per minute that a well could be pumped. My analysis of the recent pump test of Well #3 indicates that it could be pumped at 2475 gpm for 9 months to produce a drawdown of 180 feet or less. Further analysis indicates that it would recover all but about 8 feet of this in the following 3 months of it were not pumped at all. Chances are good that a higher pumping rate could be used and that the well would recover fully. Larger casing would be required to accomodate a pump rated at 2475 gpm. <u>However</u>, I performed a flow-net analysis to estimate the effect of such pumping on the water temperature, and my estimate is that 2475 gpm would lower the temperature to about 104^{o}F. Lower pumping rates would lower the temperature less. It would be possible to derive a graph of pumping rates versus estimated temperatures, if you would like to have one.

Your third question was about locating a sewage plant drain field in the area. I think it would be possible to design a drain field that would not cause cool water to move into the hot water well. It would probably have to be on the northern part of the valley bottom where the water table is low but fairly thick gravel is still present. You would have to verify that there is a sufficient area with low water table and adequate percolation rates.

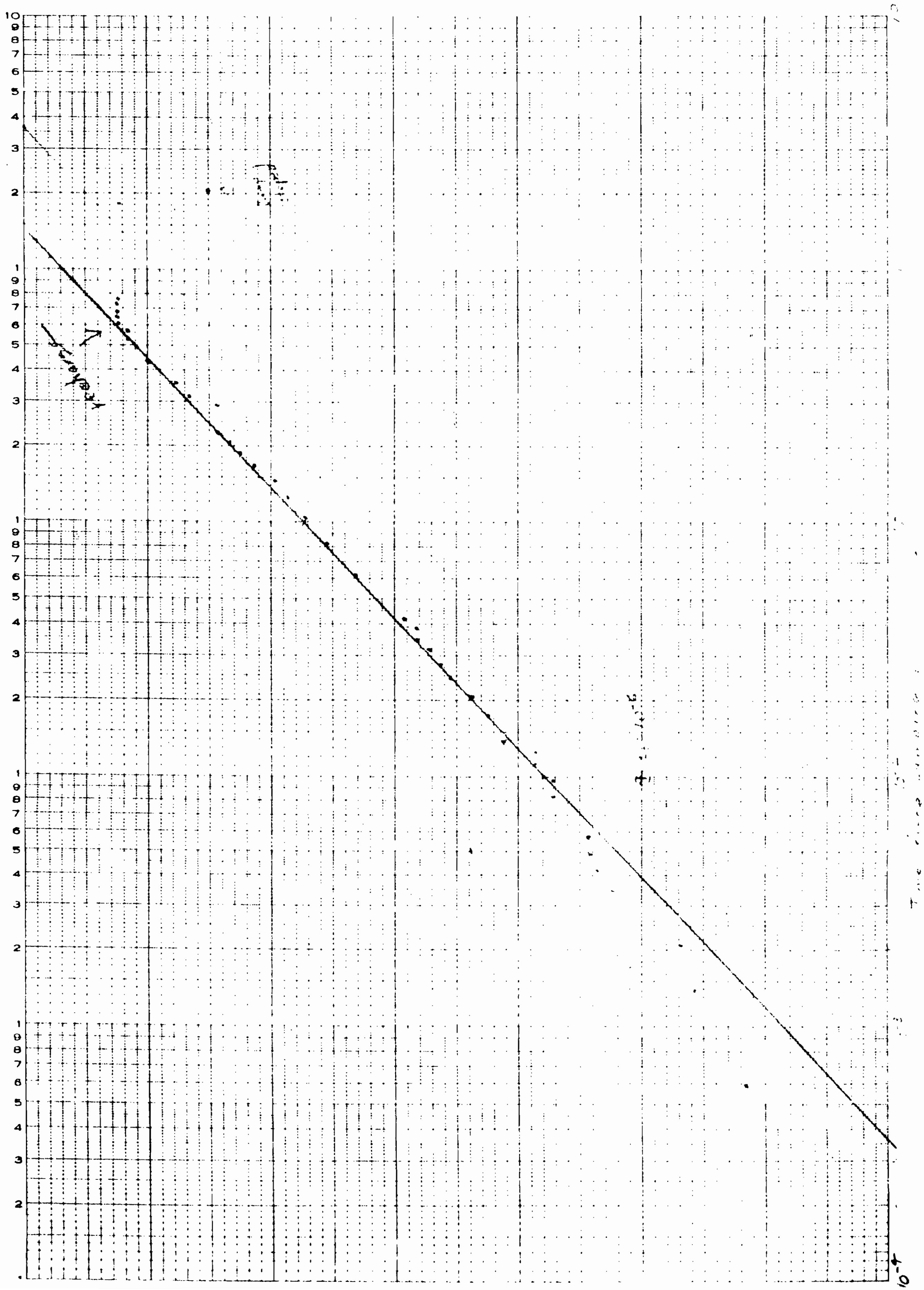
Your fourth question was about making a pond to build around. If the pond were too close to the hot water well, it would lower the water temperature. The critical distance can be estimated once you know the pumping rate of the well. If you wanted to locate a pond close to the well, you could seal the bottom of the pond.

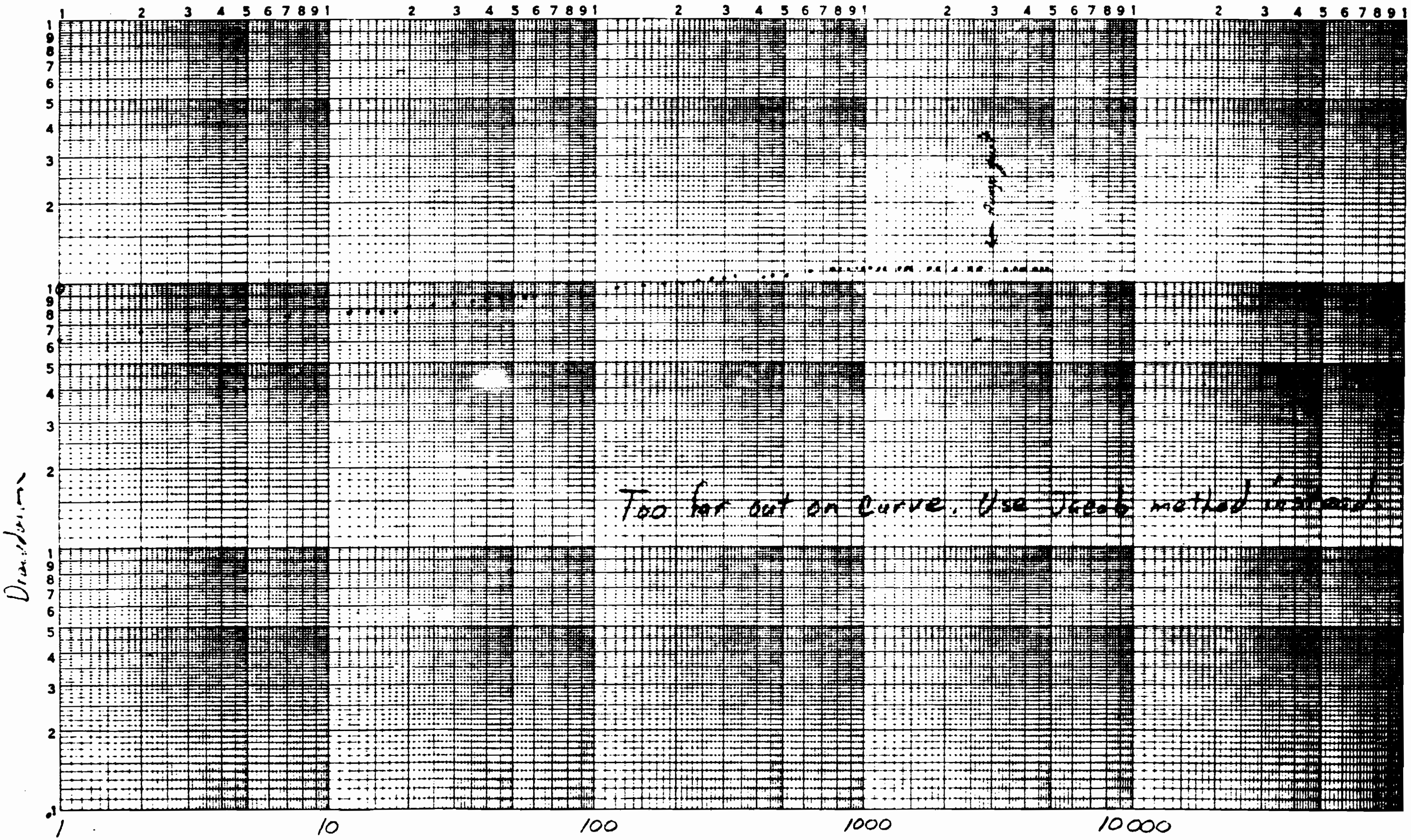
I have enclosed copies of my calculations for your file. I can explain them to you if you wish.

Sincerely,
Earth Science Services, Inc.

Darrel E. Dunn
Geologist-Hydrologist

dd
Enclosures





Time since pumping began, minutes

Pump test #2, Broadwater Hot Springs, Well #3

Pump test #2, Broadwater Hot Springs

Analysis of drawdown of well #3

Points fall where $U < 0.01$. Therefore, Jacob approximation should work

$$\Delta S = 9.73 - 7.79 = 1.94$$

$$T = \frac{264Q}{\Delta S} = \frac{264 \times 410}{1.94} = 55{,}794 \ \frac{gpd}{ft}$$

$$S = \frac{0.3 \times 55{,}794 \times 10^6}{0.25^2} = 0.27$$

Use Q = 370

T = 50,351

Sy = 0.242

Analysis of effect of pumping well #3 on water temperature on the well.

Vertical head gradient

Initial head current of well #3:

$$S = \frac{264 \times 40}{50{,}351} \log_{10} \frac{0.3 \times 50{,}351 \times 870}{0.25^2 \times 0.27} = 1.865$$

Initial head = 97.56 + 1.865 = 99.43 ft.

This was probably located at about the mid-point of the well depth.

$$\frac{\text{depth ft}}{\text{use in head, ft}} = \frac{134.93}{99.43 - 94.93} = \frac{134.93}{4.5} = 29.98$$

Use this initial head gradient on flow diagrams. Horizontal equipontential surfaces would be conservative.

Compare prediction based on 40 gpm with actual flowing temperature.

Solving the Jacob equation for r:

$$r = 10^x$$

$$\text{where } x = \frac{\left(\frac{264Q}{T} \log_{10} \frac{0.3Tt}{Sy}\right) - S}{\frac{528Q}{T}}$$

Let Q = 40 gpm

T = 50,351 gpd/ft

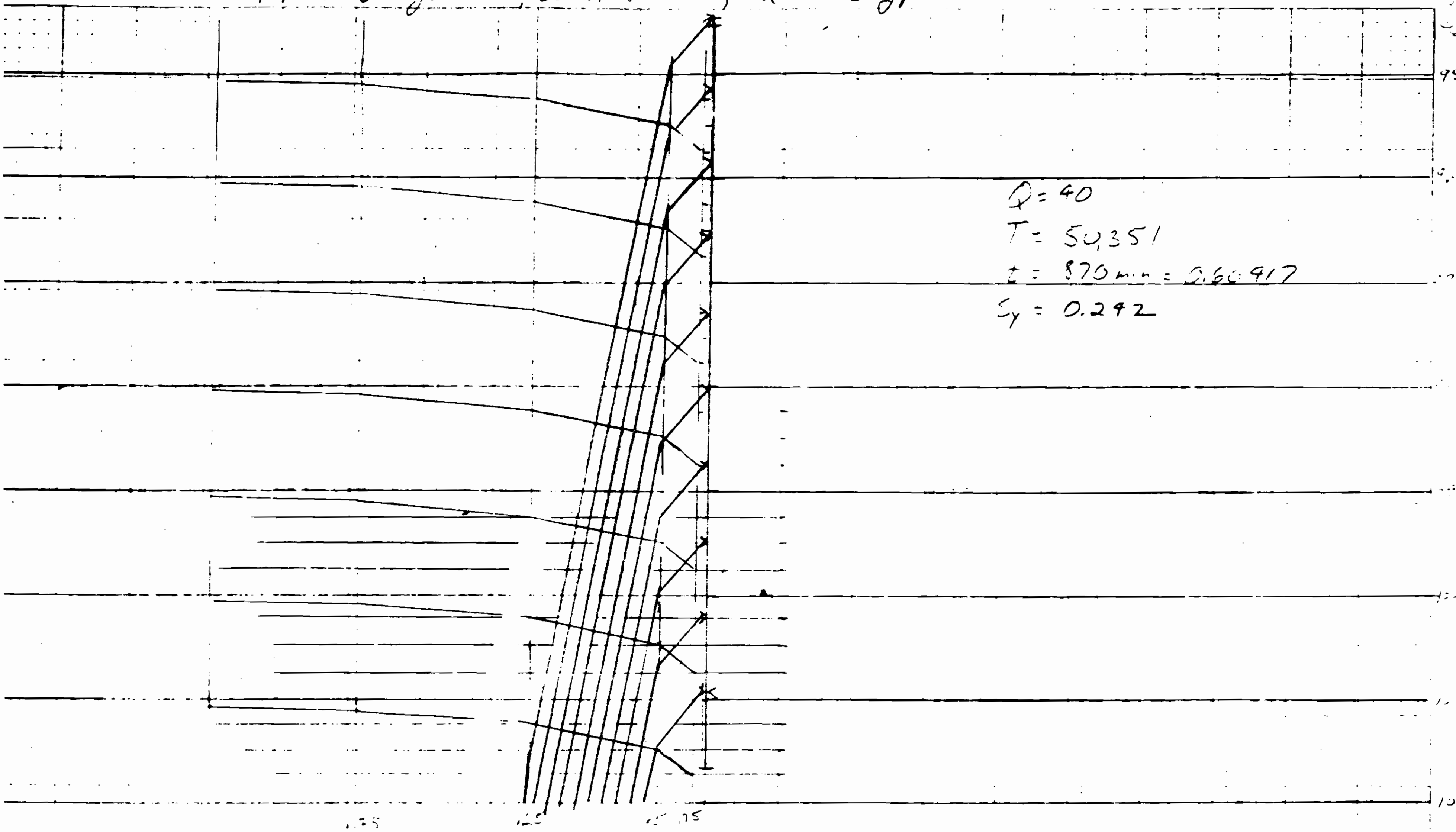
t = 870 mins = 0.60417 days

$$x = \frac{0.959813 - S}{0.419455}$$

Table of Drawdown versus Radial Distance

S	r
2	3.31×10^{-3}
1	0.802
0.75	3.16
0.5	12.5
0.25	49
0.125	97.77
0.0625	137.80

Flow diagram, Well #3, $Q = 40$ gpm



100% of flow is from 50' radius from well.
Should cause little or no change in temperature

Vertical scale = Horizontal scale
1" = 40'

Compare prediction based on 410 gpm with pump test temperature.

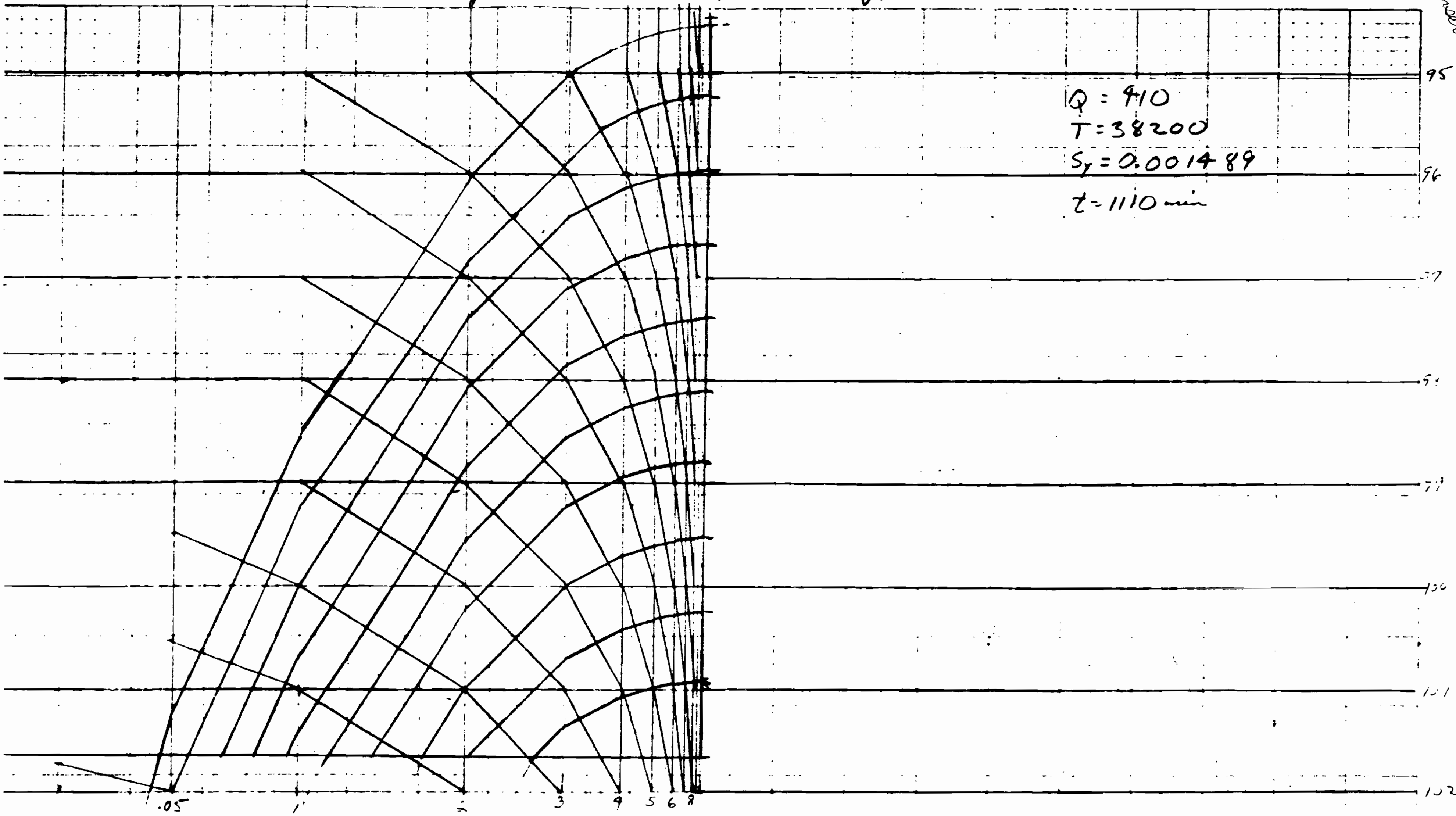
When Q = 410, $x = \frac{9.83809-S}{4.29942}$

Table of S vs r

S	r
11	0.54
10	0.92
9	1.57
8	2.68
7	4.58
6	7.81
5	13.34
4	22.80
3	38.95
2	66.54
1	113.67

2 insert ahead

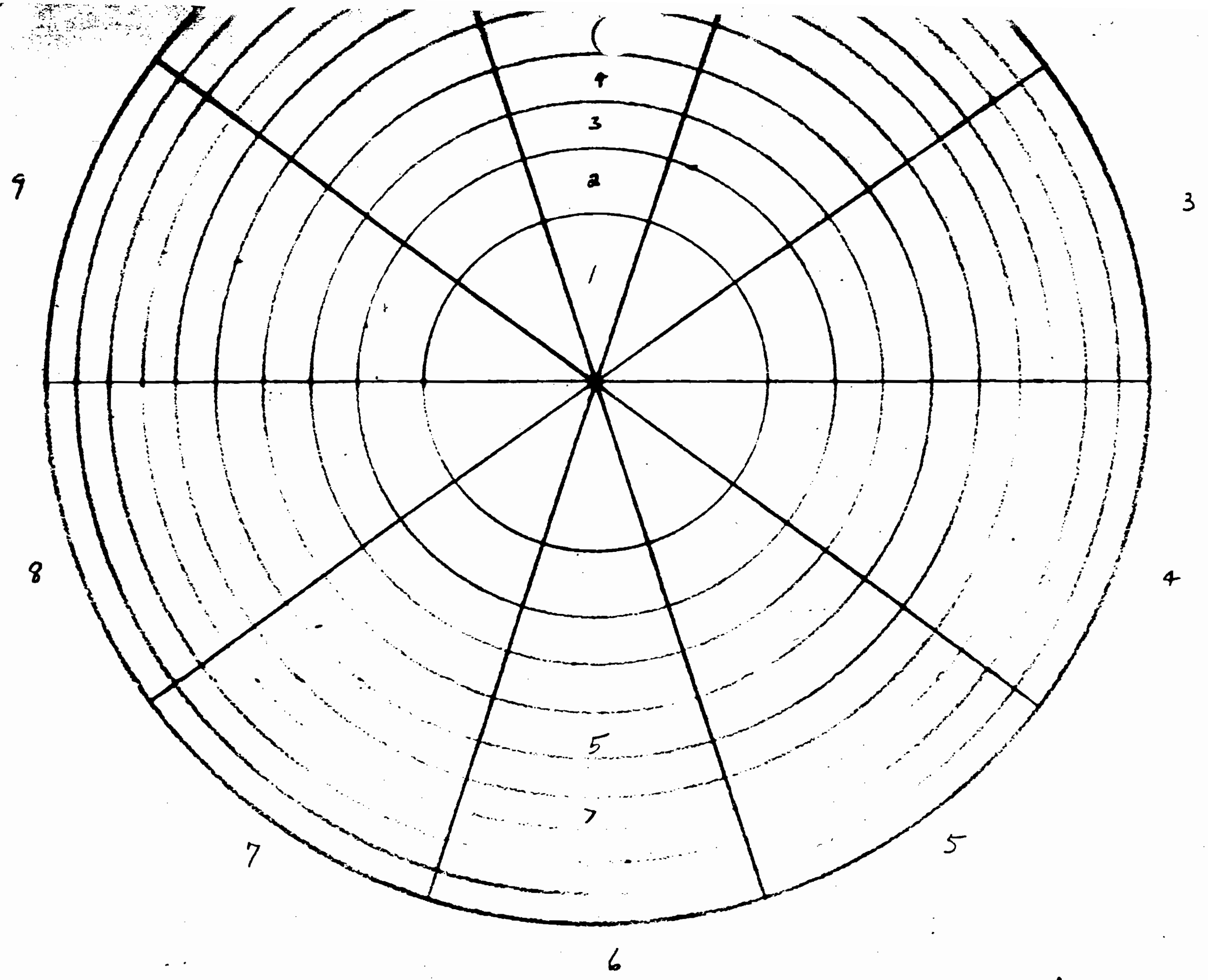
Flow diagram, Well #3, Q = 410 gpm



Q = 410
T = 38200
S_y = 0.001489
t = 1110 min

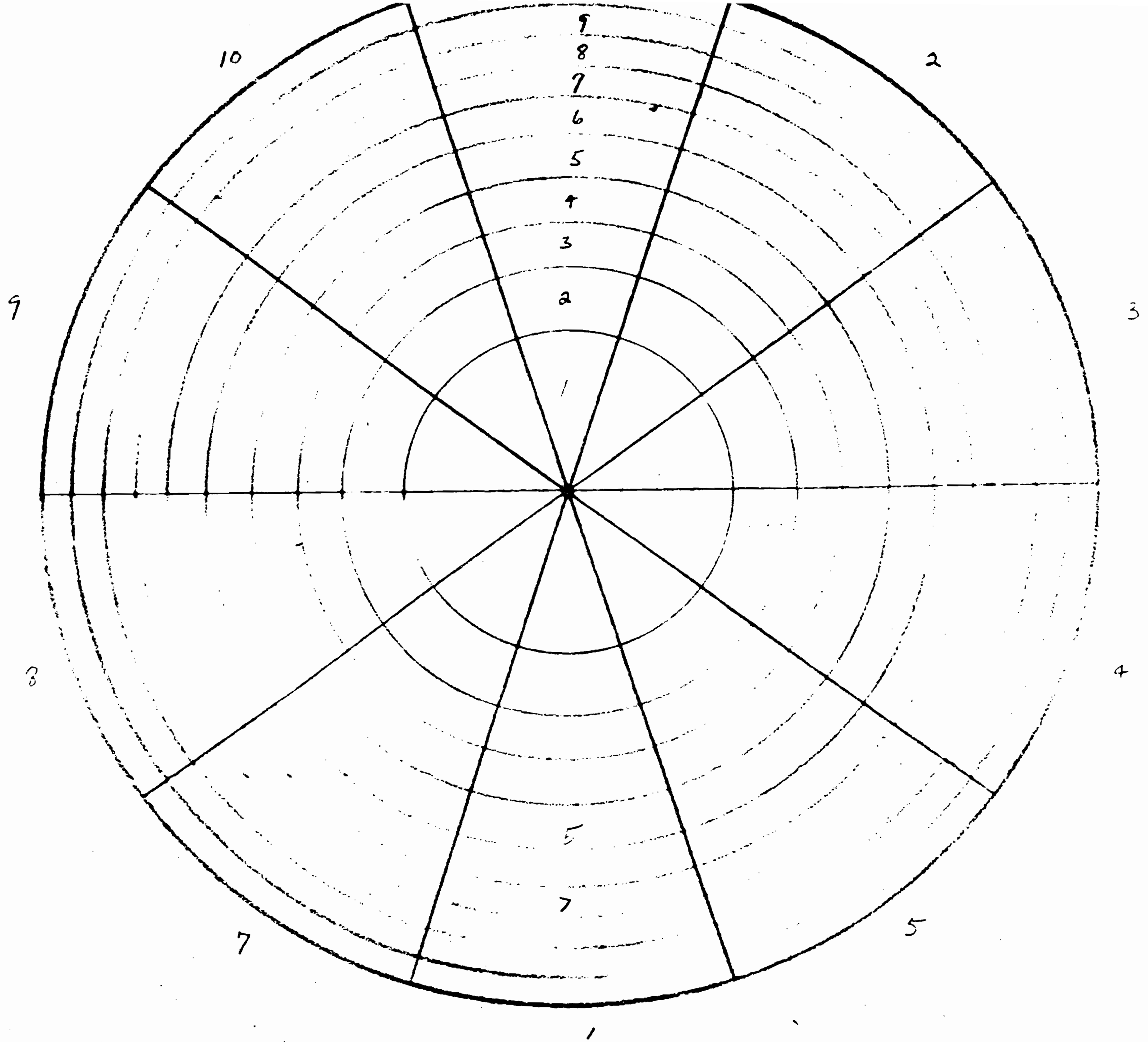
Vertical scale = Horizontal scale

1" = 40'



1% of total flow to well # 3 comes from each partition.

Superimpose of 1" = 40' bottom hole temperature map.



10
2
9
3
8
4
7
5
1
9
8
7
6
5
4
3
2
1
5
7

First digit is circle, second digit is slice

1.1	- 154	6.1	- 152
1.2	- 154	6.2	- 140
1.3	- 154	6.3	- 139
1.4	- 154	6.4	- 150
1.5	- 154	6.5	- 151
1.6	- 154	6.6	- 152
1.7	- 154	6.7	- 152
1.8	- 154	6.8	- 154
1.9	- 154	6.9	- 154
1.10	- 154	6.10	- 154
2.1	- 154	7.1	- 150
2.2	- 154	7.2	- 139
2.3	- 154	7.3	- 135
2.4	- 154	7.4	- 150
2.5	- 154	7.5	- 151
2.6	- 153	7.6	- 152
2.7	- 153	7.7	- 152
2.8	- 154	7.8	- 154
2.9	- 154	7.9	- 154
2.10	- 154	7.10	- 154
3.1	- 154	8.1	- 150
3.2	- 152	8.2	- 135
3.3	- 151	8.3	- 130
3.4	- 153	8.4	- 145
3.5	- 153	8.5	- 151
3.6	- 153	8.6	- 151
3.7	- 153	8.6	- 151
3.8	- 154	8.8	- 154
3.9	- 154	8.9	- 154
3.10	- 154	8.10	- 153
4.1	- 154	9.1	- 145
4.2	- 150	9.2	- 130
4.3	- 150	9.3	- 130
4.4	- 152	9.4	- 145
4.5	- 153	9.5	- 151
4.6	- 152	9.6	- 151
4.7	- 152	9.7	- 151
4.8	- 154	9.8	- 154
4.9	- 154	9.9	- 154
4.10	- 154	9.10	- 153
5.1	- 152	10.1	- 142
5.2	- 145	10.2	- 120
5.3	- 142	10.3	- 120
5.4	- 151	10.4	- 151
5.6	- 152	10.6	- 151
5.7	- 152	10.7	- 151
5.8	- 154	10.8	- 154
5.9	- 154	10.9	- 154
5.10	- 154	10.10	- 152
			150.06 checked

The temperature prediction method checks ok with the pump test.

Now make a computation for the maximum likely capacity of the wells.

Use 180 feet for available drawdown (most of water may be coming from 135-180 feet.)

Use aquifer coefficients from well #4

$T = 38{,}200$

$Sy = 0.001489$

$r = 0.25$

$y = 9 \times 30$

$S = 180$

$$Q = S \times \left(\frac{1}{\frac{264}{T} \log_{10} \frac{0.3Tt}{r^2 Sy}} \right)$$

$$= \frac{180}{0.0727159} = 2475 \text{ gpm}$$

How much would it recover in 3 mo?

$S = 172$ i.e. would recover all but 8 ft.

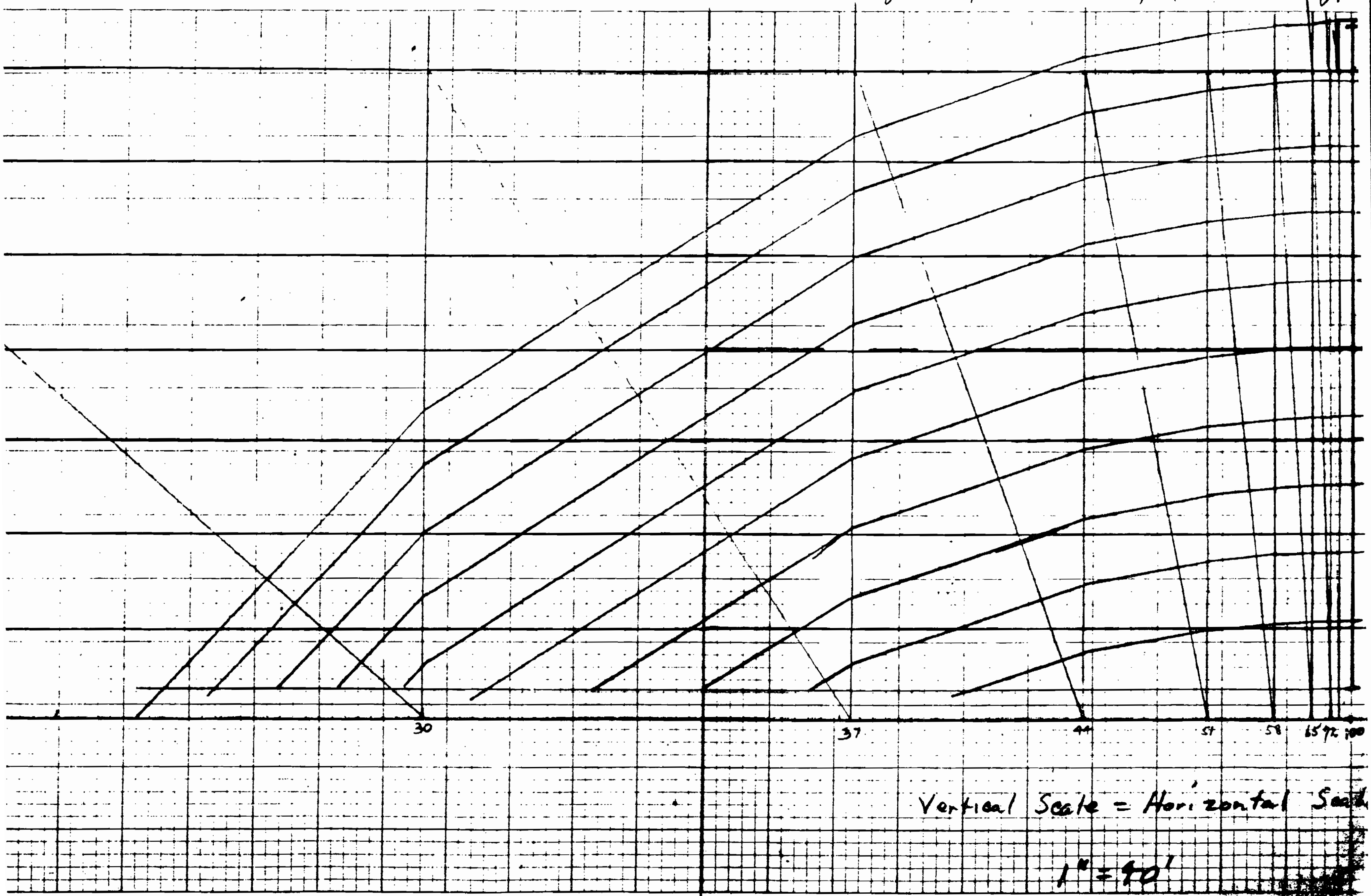
Actually the cone will probably hit 10-miles cr. and stabilize before 8 ass.

Prediction based on pumping well #3 at 2475 gpm for 9 months.

Use $t = 270$ days $\quad x = \frac{93.7799-S}{25.9538}$

S	r
100	0.58
93	1.07
86	1.99
79	3.71
72	6.90
65	12.85
58	23.91
51	44.49
44	82.80
37	154
30	287

Flow diagram, Well #3, Q = 2475 gp.



Vertical Scale = Horizontal Scale

1" = 40'

Temperature at Q= 2475, Well #3

1-1	153
-2	153
-3	154
-4	154
-5	154
-6	153
-7	152
-8	150
-9	153
-10	153

1529

2-1	151
2-2	150
-3	153
-4	154
-5	153
-6	150
-7	130
-8	110
-9	140
-10	150

2970

3-1	148
-2	140
-3	153
-4	153
-5	150
-6	142
-7	95
-8	80
-9	120
-10	151

4302

4-1	140
4-2	130
4-3	152
4-4	152
4-5	140
4-6	110
4-7	60
-8	60
-9	100
-10	151

5497

5-1	110
-2	95
-3	145
-4	145
-5	110
-6	85
-7	50
-8	50
-9	95
-10	151

6553

6-1	85
-2	70
-3	140
-4	135
-5	100
-6	80
-7	60
-8	60
-9	85
-10	80

7448

7-1	60
7-2	70
7-3	135
7-4	100
7-5	80
7-6	60
7-7	60
7-8	60
7-9	90
7-10	120

8283

8-1	60
8-2	65
8-3	120
8-4	100
-5	70
-6	60
-7	60
-8	60
-9	80
-10	110

9068

9-1	60
-2	60
-3	100
-4	80
-5	60
-6	60
-7	60
-8	60
-9	70
-10	90

9768

10-1	60
-2	60
-3	90
-4	70
-5	60
-6	60
-7	60
-8	60
-9	70
-10	80

10438

104°F

The main source of extra energy is bringing in warm water from a much larger area. You are also taking water from storage. Picking up energy stored in the rock material, increasing the upward flow rate, reducing evaporation etc.

BALZHISER AND COLVIN ENGINEERING, INC.

860 McKINLEY STREET • P. O. BOX 2687 • EUGENE, OREGON 97402 • (503) 686-8478

JAMES K. BALZHISER, M.E.
CARROL C. COLVIN, E.E
Registered Professional Engineers

February 4, 1977

Mr. Frank Gruber
6240 Center Drive
Helena, Montana 59601

Re: Hot Well Utilization

Dear Frank:

First, I wish to thank you for the courtesies you extended to me on my recent visit to Helena. It was nice to have such good weather.

We have done a considerable amount of thinking and calculating on your problem. With your development of the well to date you have a usable capacity assuming 600 gpm and a temp. differential of 50 deg. F. equal to 15 million Btu/hr. which is the equivalent of burning 125 gal. of oil/hr. This is sufficient to heat 300 apartments assuming 50,000 Btu/hr. heat loss.

At that point of usage there is still available heat in the water that could be used for heat pump heating, heating swimming pool, or any low temperature application.

We cannot at this point predict what the ultimate use of the water will be or what the most economical method of distribution will be, but can give you some of the limiting factors and guide lines as follows:

1. We do not recommend using the well water direct in heating system because of the possible corrosion and mineral built-up in the system.

2. For a small system (single family residence up to a four-plex) we would recommend a down hole heat exchanger system with a closed loop distribution system.

3. For a large system where you intend to use the full capacity of the well system then we recommend using a heat exchanger system. The heat exchanger could be located at the well or remote, depending on building location and general layout. The heat exchanger should not be located where there would be more than 50 ft. vertical rise from the heat exchanger to the highest building.

4. The hotter the well water the less would be the cost of the heat exchanger. The 150 deg. is about minimum for a heat exchange. For this reason I feel it would be well for you to consider drilling a larger well and seal off all water above the 100 ft. level. Also

I would consider drilling to at least 300 ft. I do not recommend this until after you are committed to the larger project.

Attached are two statements for the application, that is "Work Statement" and "Recommended Budget". As you will note the estimated budget is above the $15,000.00 grant. If you were to cut this to a tri-plex the budget could be reduced by about $2,500. which would put it about equal to the grant. I feel my estimate is on the high side but until the building is designed it is as close as I dare guess.

I trust this gives you the data you were looking for and that your project will move ahead rapidly. Please contact us if we can provide additional date relative to this stage and for the final design.

Aincerely,

James K. Balzhiser

James K. Balzhiser, P.E.

JKB:j

enc.

APPENDIX B

WORK STATEMENT

We propose to deisgn and install a complete "Geothermal Heating System" for a four-plex living unit, including heating of domestic hot water. Attached is a schematic sketch of the proposed system.

This system is an adaptation of what has been done on similar projects at Klamath Falls, Oregon although with improvements.

Basically the heating pump would operate continuously (1/2 H.P.) pumping water in a closed system to a furnace (air handler) in each living unit where it would go through a coil to heat the water, and through a small side arm heater to heat the domestic hot water. We anticipate the water to enter at 140 deg. F. minimum at the furnace and leave at 100 deg. F. under design conditions. The temperature within the living unit will be controlled by a room thermostat to start and stop the fan, hand valves could turn the water off in the summer if desired, or an automatic valve could be added.

The hot water would also run continuously through a side arm heater to heat the domestic hot water. We recommend that the storage tank be a standard 52 gal. electric, so that on heavy usage the electric could operate to boost the temp. if needed.

The final engineering design of this system will be done as soon as the type of structure is known. We are recommending a structure that is insulated and designed to meet the ASHRAE 90-75 standard.

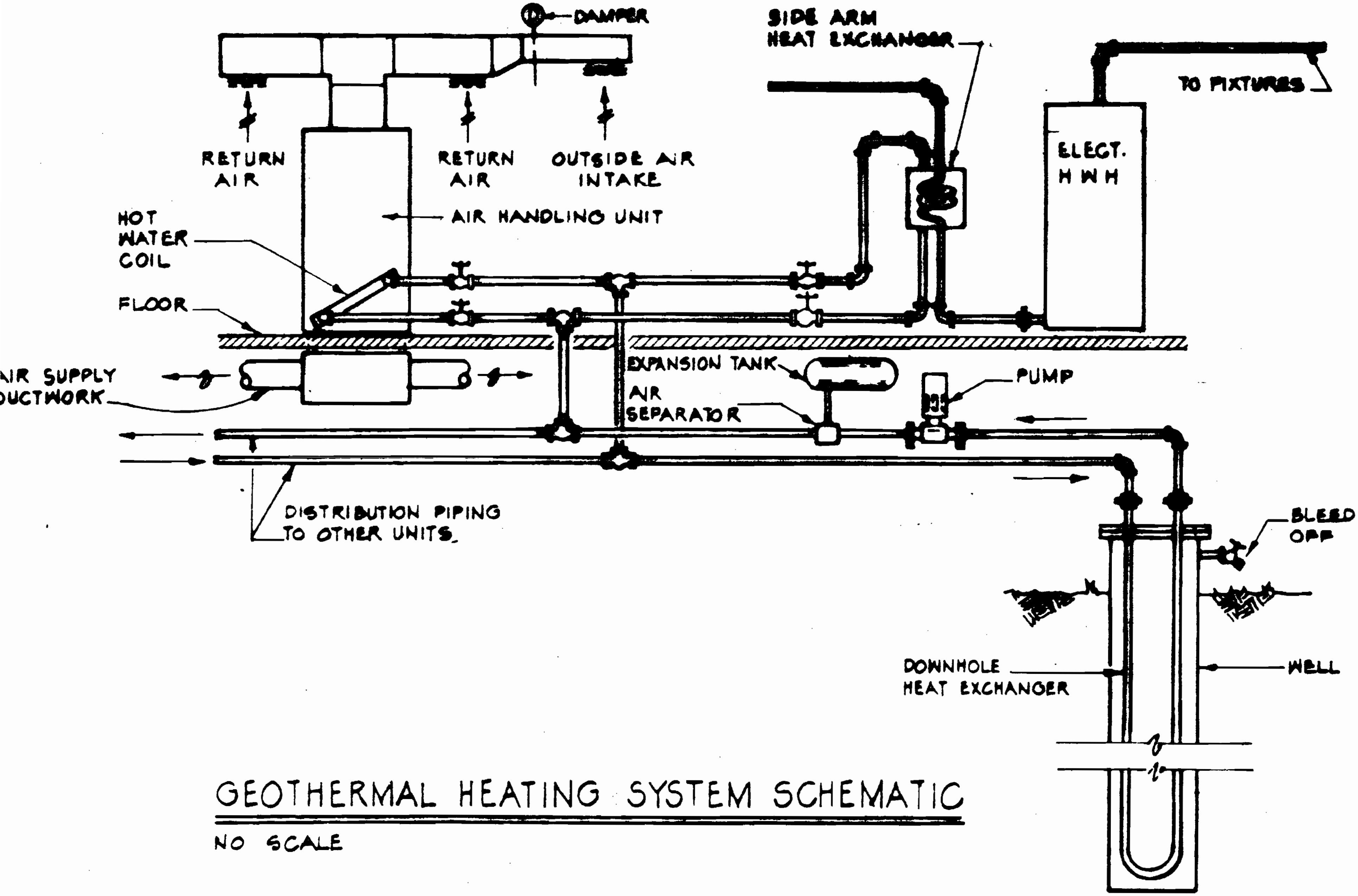
APPDENIX C

RECOMMENDED BUDGET

Down Hole Heat Exchanger, 380 ft.		$ 900.00
Distribution Piping 400 ft. @ $5.00/ft.		2,000.00
Pump, Expansion Tank and Accessories		900.00
Air Hanling Unit, Coil & Controls		
	4 @ $750.00 ea.	3,000.00
Duct Work	4 @ $1,500.00 ea.	6,000.00
Metering and Controls		1,000.00
		$13,800.00
	10% contingencies	1,300.00
		$15,100.00
	Engineering	2,500.00
		$17,600.00

Above estimate of cost figures include contractors overhead and profit. It is assumed that the owner will lay the underground distribution piping.

The difference between the estimated $17,600.00 and the $15,000.00 grant will be paid by the grantee.



GEOTHERMAL HEATING SYSTEM SCHEMATIC

NO SCALE

BALZHISER & COLVIN
ENGINEERING, INC

EG&G Idaho, Inc.

P. O. Box 1625
Idaho Falls, Idaho 83401

Soc Keller
~~208-572-6640~~
Ph -208-526-1533

5 October 1977

Mr. Frank Gruber
6240 Center Drive
Helena, Montana 59601

BROADWATER RESIDENTIAL HEATING SYSTEM - JGK-34-77

Dear Mr. Gruber;

The meeting held 9-22-77 was most beneficial for understanding the nature of your geothermal development. As was presented earlier, the chemical analysis reveals no special materials problem and therefore, standard copper may be used for heat transfer areas and chlorinated PVC schedule 40 pipe for transporting the water from well - house - discharge.

The geothermal heating system therefore is essentially the same as a hydronic (hotwater) system where the geothermal water is being used to replace the fossil-fuel fired boiler. One different item would be providing domestic hot water from the geothermal water. With the Fluoride content above those set by national standards, it is suggested that you not use the geothermal water directly. One alternative would be to use a hot water storage tank developed for the solar market. These tanks have an inside coil for circulating solar heated water and could be used for circulating geothermal water equally as well. This circulating coil is used to transfer heat to domestic cold water.

Enclosed are the following: 1) McQuay literature on large size fan-coil heating units;

and 2) A simplified diagram of how to connect the geothermal heating system.

From the diagram, it is seen that the major equipment items will be a well pump, expansion tank, air eliminator, fan-coil units, and the solar storage tank. The expansion tank and air eliminator should be sized once your total system capacity has been established. The fan-coil unit sized for a 1200 sq. ft. house in Helena, Montana should deliver approximately 50,000 Btu/hr. Two McQuay units that size are:

SHD-081A 6 row, 800cfm, 5.7 gpm, $395.40

SHD-121A 3 row, 1200 cfm, 6.3 gpm, $432.00

Other fan-coil units may be used depending upon the water flow rate and air velocity desired. The enclosed McQuay brochure will help determine the unit to choose.

The hot water storage tank (solar) should be available from a Montana solar equipment company. One such company here suggested a Ford brand name: Ford TC-65. This particular model has a capacity of 65 gallons storage, 1-3/4 inch fiberglass insulation, 3/4 inch copper coil and costs $321.00. Temperature controllers (standard) are required to regulate solenoid valves (extra) to control the geothermal water flow.

The above mentioned equipment items should be presented to the heating contractor for his final design and selection. If we can be of further help in the design or construction phases, please feel free to contact the undersigned.

Very truly yours,

Joe G. Keller
Geothermal Projects

ajw

Enclosures
As Stated

1. Annual heating requirements

= 12,000 x DD/year

= 12,000 x 8190 = 98.28 million Btu/year

2. Hourly heat requirement

= 600 (65 - (-17))

-17 = 99% of time the temperature is above -17^{o}

= 49,200 Btu/hour

+ 25% overload = <u>12,300 Btu/hour</u>

Total = 61,500 Btu/hour

3. Flow rate

61,500 Btu/hour = 500 x gpm x ΔT $\Delta T = 20^{o}F$

$$\frac{61,500}{500 \times 20} = \text{gpm}$$

6.15 gpm = gpm

4. Piping @ 5 feet/sec velocity

@ 10 gpm for heating & providing hot water

5'/sec x 60 sec/min x X square feet = 10 gpm x 0.1337 ft^3/gpm

x = 0.004456 ft^2

or radius = 0.45"

diameter = 0.90"

5. Hot water requirements @ 50 gallon tank

@ 22 gallon/hour recovery

@ 5.5 kW input for electrical type

$$5.5 \text{ kW} \times \frac{3412 \text{ Btu}}{\text{kW}} = 18{,}766 \text{ Btu/hr} = 50.0 \times \text{gpm} \times 20^{o}\text{F}$$

$$\text{gpm} = 1.88 \text{ gpm} = 2 \text{ gpm}$$

6. Plastic CPVC pipe schedule 40 1" rated at 215°F and 264 psi.

cost: $1.30/foot pipe

$3.60/foot installation

2.15/cubic yard trenching @ 3' depth

$0.46/cubic yard fill

trenching and fill for 200'	= $ 522.00
piping 200'	1,290.00
Total	= $1,812.00

7. Discharge

cost as above

500 x flow rate x temp. drop = Btu per hour

PVC schedule 40 - 140° @ 60 PSI

CPVC schedule 40 - 160° @ 180 PSI

..PICAL HOT WATER DISTRIBUTION SYSTEM

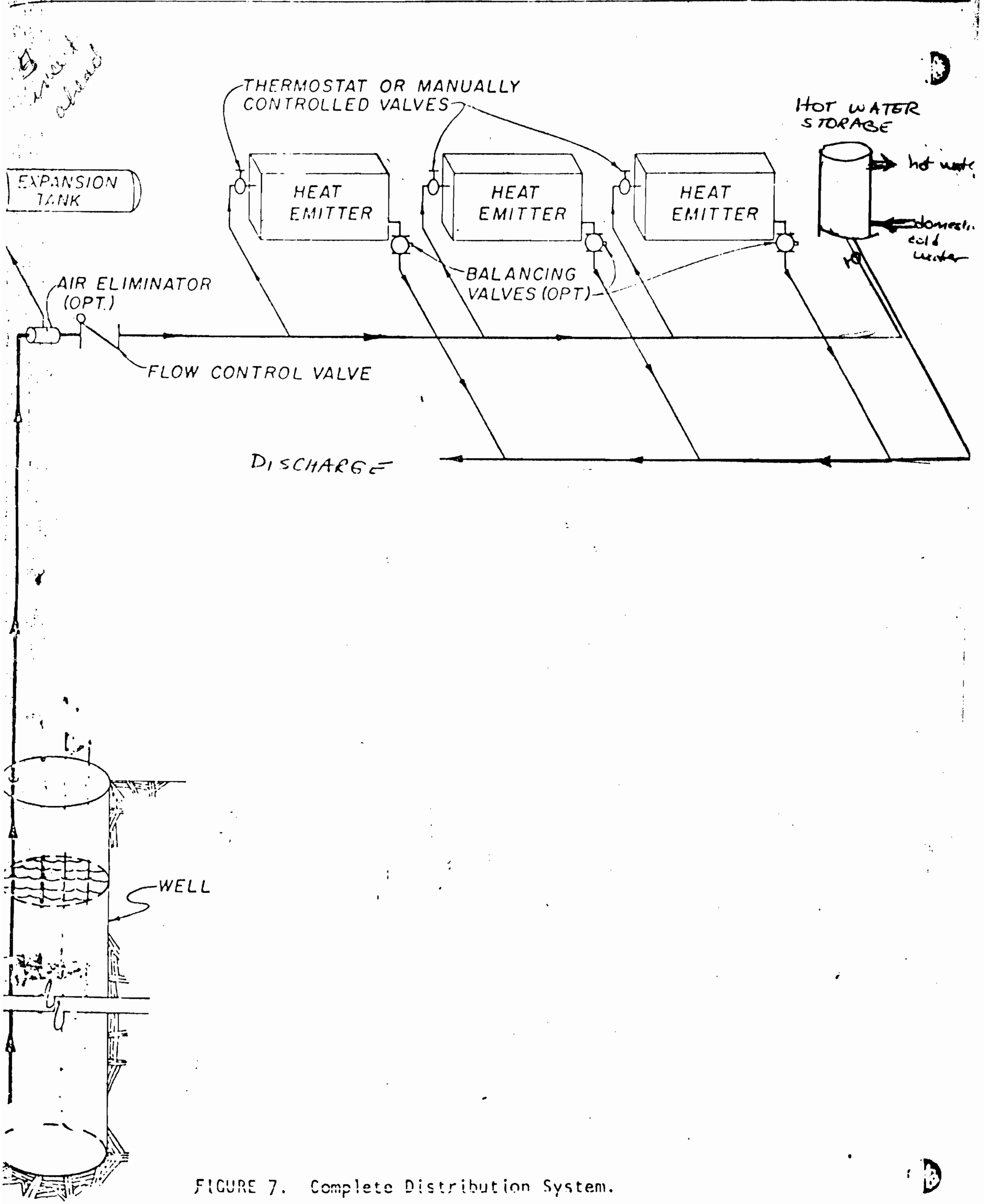


FIGURE 7. Complete Distribution System.